TREASURES OF THE EARTH

TRIUMPHS OF ENTERPRISE

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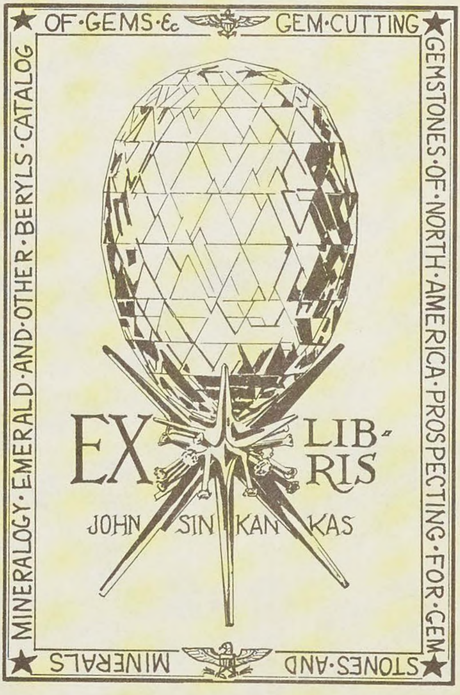

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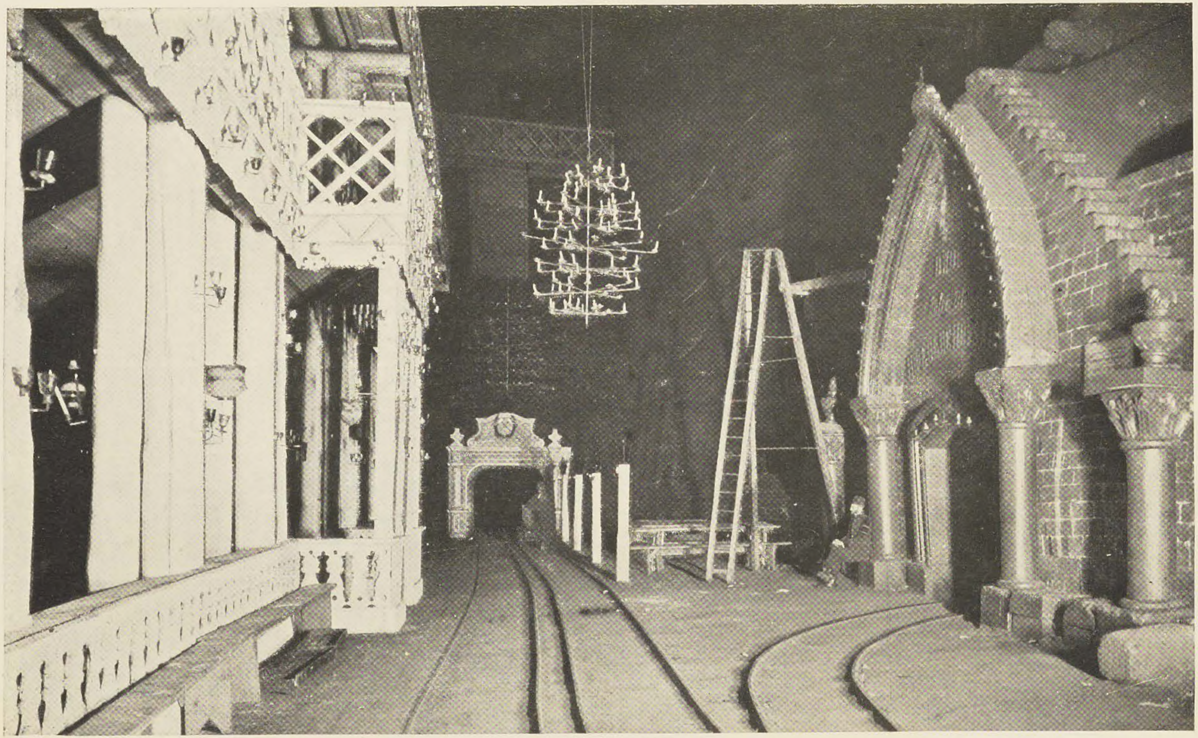
Triumphs of Enterprise

TREASURES OF THE EARTH



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AN UNDERGROUND CITY OF SALT

The most wonderful salt mines in the world are those of Wieliczka, about six miles from Cracow, in Polish Austria. Hewn out of the rock salt are to be found roads, streets, houses, monuments, and churches. Above are seen a restaurant and railway station.

Treasures of the Earth

BY

CYRIL HALL

Author of "Conquests of Engineering"
"Wood and What We Make of It"
"Wonders of Transport" &c.

ILLUSTRATED BY THIRTY-TWO REPRODUCTIONS FROM PHOTOGRAPHS AND MAPS

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Prefatory Note

This book is an attempt to give some idea of the extraordinary richness and importance of the mineral substances of the earth. It has not been possible to give within so small a space more than a very brief account of the most important of these treasures; and if it is complained that my story ends almost at the beginning, my retort is that I have tried to say enough to bring before my readers some idea of the wonders of geology. Since the days of Robert Dick fossil hunting has ever been a favourite pursuit of boyhood; but if read aright the story of the fossils is of an interest far surpassing that of the trophies themselves. No branches of science have made such stupendous strides in recent years as metallurgy and economic geology, and to none is the world more greatly indebted for its comforts and conveniences. Scarcely less remarkable is the transition from the rough flint tools of the first quarrymen to the elaborate appliances at mine, laboratory, and workshop at the present day.

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TREASURES OF THE EARTH

CHAPTER I

The World we Live In

"The world is so full of a number of things
I am sure we should all be as happy as kings."

PROBABLY we are, if we only knew it. Outside the fairy tales, a king has a sufficiently difficult and monotonous life. Pleasure must give way to business, inclination to duty, with him as with all of us. And in this we are his equals, that the sun shines, the earth buds and blossoms, and the birds sing, as well for us as for him. If we have eyes to see, the beauties of Nature are spread before us everywhere. We can walk by her side and listen to her wisdom, and she will show us the way to happiness. Even in the streets of the dark and dreary city we can be reminded of her mysteries. What makes the city dark? Smoke. What makes the smoke? Coal, mostly. Why are there so many fires? To keep the great city alive, to make food for the world, ships for the world, guns for the world, needles and pins for the world, china, glass,

motor-cars, bicycles, railway trains, typewriters, teapots, ploughs, church bells, sanitary appliances, surgeons' knives, and babies' cots—everything and anything a community of civilized people requires. And as none of these things can be made without heat, so none of them can be made without material. And the material comes direct from Nature.

Just think a little. Tucked away under the earth's green mantle are the substances essential to the making of *everything*. These substances have been there ready for our use for countless ages. They have only been waiting to be discovered. They are not impatient. It took billions of years for them to form, and they are quite content to wait a few thousand years more. Compared with theirs, man's progress has been meteor-like. Man has been on the earth during only an insignificant fraction of their lives, yet what has he not achieved? First, he discovered the uses of stone, the material before his eyes, and made stone weapons, stone tools, stone temples. Next (a great advance), the possibilities of iron—iron weapons and tools: glass, pottery, bricks, the precious metals—he is becoming civilized now: then lead, tin, copper, alloys, and amalgams and the primitive steel: lastly, coal and all the wonderful processes it has made possible. What will he find next? We cannot foretell, but we know that he is only on the fringe of discoveries connected with radium and kindred rare metals. Gold from dross, perpetual motion, the philosopher's stone, all the dreams of ancient alchemists seem as prophecies in the light of recent scientific developments.

Baldly stated, it sounds little enough. Considered in detail, what a contrast lies between your father and the man of the Stone Age! Mr. Man of the Stone Age was an uncouth creature, dressed in skins which his wife had sewn together with a fish-bone needle and fibres from a plant stalk or a tree trunk. When he got up in the morning he may or may not have had to light the fire; that would depend upon circumstances. Whether he or his wife did it, they had no sulphur and phosphorous matches, but two bits of wood, which they rubbed together until a spark came. As a matter of fact they probably kept the fire alight all night. Breakfast over, Mr. Primitive Man had to go to business, just as your father does, but with a simpler object. When your father goes to business he does it to get house rent, school fees, grocery, greengrocery, bread, meat, milk, and wine. He wants money for the doctor, the dentist, the house decorator, the cobbler, the draper, the milliner, the hatter, the tailor, and a host of other people. Mr. Primitive Man had only one end in view. He was a butcher and nothing else. His stock-in-trade consisted of a stone dagger—you may see it in a museum. His wife possibly grew a little corn and kept a goat or two. They lived in a cave and dressed in the skins of the beasts the man killed. I do not suppose they had any lamps. If they had they burnt the fat from the same source, and a nice savoury abode their cave must have been on a winter's night! But they had, as a rule, enough to eat and a fire to warm them. They wanted nothing else. If hard weather came and the man could get no meat, they starved.

But what a lot of things your father must have! His nice warm brick house with the plaster lining, all properly fitted up with lead pipes, porcelain baths with nickel taps, electric bells and light, gas stoves, telephones, and "all modern conveniences" as the house agents say. When he goes out he wears beautiful clothes woven by machinery from wool spun by machinery; he steps on to a tiled or asphalted path, goes to the station in a tram-car, gets into the train—— But have you ever stopped to think that all these comforts and refinements of life are due to the mineral wealth of the world? Not all the science and theory of all the sages could have advanced us without the material. The wife of Mr. Primitive Man dug a little with her stone trowel and grew a few pot-herbs. She could never have done more without better tools. Her husband made a little boat of skins and boughs and paddled about the river or near the sea-shore. He could not venture far in it, but then he could only manage the roughest of carpentering with his stone axe. Directly men discovered how to make use of iron they began to advance. Hammers, picks, crowbars, knives, spades, all sprang into existence. Buildings took the place of skin huts and cave dwellings; crafts developed, and with the crafts skilled craftsmen. On the heels of the boatbuilder came the boatmen, and following after the boatmen came a race of explorers. Wealth began to appear in the land, at first a wealth of flocks and herds, wool and salt, flour and fine linen, but presently wealth of another sort—the tangible, undeniable wealth of money.

But apart from metals, stones, and rocks, there are other sources of wealth concealed in the earth. To begin with, there are all the substances necessary to plant life, such as iron, carbon, nitrogen, and many soluble salts. The farmer and the market-gardener make a livelihood by forcing the earth to give up these substances to plants, and we, by eating cabbages and flour, maintain strength in our own bodies. If we were cabbages ourselves we could digest these substances as they exist in the ground; but as we are not, we take the cabbage, which consists simply of partially-digested carbon, nitrogen, salt, and water. Besides, there are in the ground countless organisms which make cultivation possible. We call them bacteria, and as yet we know very little about them. But they are there, and they are the farmers' very best friends. We cannot refuse to mention them therefore, although, being living organisms, they are not strictly the kind of earth treasure with which this book professes to deal. However, since they do exist actually in the earth they may be considered as *of* it, but I will not be drawn still farther aside into discussions of the mole and the earthworm, Nature's ploughmen though they be.

Now, to every thoughtful-minded person an immense question presents itself. How did all these things come to be in the earth? It is not an easy question to answer. In fact it cannot be answered without a careful study of several intricate sciences. Geology is not enough, mineralogy is not enough. Palæontology, physics, and chemistry all must be consulted, and even then, unless you are a very extra-

ordinarily clear-headed person, you will close your books with a very muddled and hazy conception of the whole business. It may help you a little perhaps if I give you a very short and broad summary of the natural forces which are at work in our world. It is to the efforts of these forces that the present face of the earth is due no less than the interior. They govern the movements of man himself as well as the movements of the mysterious and terrible contents of the centre of the earth. They are the two forces of Segregation and Disintegration.

You must remember that now we are dealing with things which have had no beginning. Our little minds cannot comprehend eternity, yet no period of time can embrace the making of the earth. Geologists attempt to fix the age of certain rocks, but their results are rarely identical. They can only fix the comparative positions of the various geological systems. The law of continual change governs the universe, but investigators have managed to establish definitely the order in which the great changes have taken place. Always, however, they are confronted with "Before that?" No matter how far back they search they can find only developments. They never find a beginning. Let us start our story, then, since we cannot find the origin of all things, at the point where there were no sun, moon, stars, earth—"no nothing".

"It was Time's morning
When Ymer lived;
There was no sand, no sea,
Nor cooling billows;

Earth there was none,
No lofty Heaven;
No spot of living green—
Only a deep profound."

So runs an Icelandic saga of some twelve hundred years ago. It would be more correct, as a matter of fact, to imagine a great revolving mass of incandescent matter of the same constitution as our sun is now but very much hotter and bigger—a great catherine wheel whirling round and round. That is what this mass of "nebula" was like, a flaming wheel from which sparks were constantly flying off. The sparks then began an independent existence, following the movements of the mother wheel at a respectful distance. They became, in fact, worlds. Our earth was one of the sparks—a very small one, although we think it such a wonderful place. Once the earth had separated from the bulk of the nebula it began to cool. At the same time, of course, it would become sensible of the heat and light of the nebula, round which it continued to revolve. Now notice one thing. According to *Genesis*, the first step in the creation of the world was the production of light. Religion and science, unfortunately, often work along different lines. It is by no means an impossible thing for atheism and science to walk together. Yet men of science in their investigations into the history of the earth have proved indisputably the order in which the successive stages of development occurred. Can we regard it only as coincidence that this order is exactly the same as that recorded in *Genesis*? Call it a coincidence if you like. What are the odds?

Have you ever heard of an Oxford treble-bob maximus? It is the name applied by bell-ringers to the feat of ringing 5136 changes on a peal of twelve bells. But if twelve bell-ringers were to ring an Oxford treble-bob maximus every day it would take them over 90,000 days to finish ringing all the changes possible on a peal of twelve bells. They would have to ring 479,001,600 changes! If you were asked to repeat, say, the thirty-thousandth change, the odds would be 479,001,599 against you. It would be a very startling coincidence if you picked out the right one, would it not? Well, let us take another example. A famous firm of locksmiths makes its keys on a system of permutations. The keys have fifteen wards, and these wards are arranged differently, so that no two keys are alike. There is no danger of exhausting this device, for the number of possible arrangements of fifteen wards is 1,307,674,368,000. Besides, a reduction or increase in the number of wards would immediately open out a new field of variations. A billion, perhaps, is rather an empty name. It becomes more vivid when we estimate 1000,000,000,000 seconds as occupying 30,000 years.

Moses, as you know, wrote out the book of *Genesis*. We have no reason whatever to suppose that he knew anything about geology. In those days nobody did; and on the tomb[1] of Seti I, whose daughter rescued Moses from the bulrushes, is a representation of the sun going round the earth, which does not argue any sound astronomical learning. Moreover, a knowledge of geology has only been acquired by travel and study

[1] In Sir John Soane's Museum, Lincoln's Inn Fields.

of different portions of the earth's crust. In the time of Moses people did not travel, and much of the globe was entirely unknown to the Egyptians. We must acknowledge that Moses got his facts right either by divine inspiration or by the most astounding coincidence the world has ever imagined. As the fifteen wards of the key could be re-arranged, so could the fifteen epochs of creation. If I tried to write down all the permutations of these fifteen events it would take me eighteen million years, and I am not likely to live as long. I can hardly do better than quote from *Moses and Geology*, by the Rev. Samuel Kinns, Ph.D., F.R.A.S.[1] He speaks with more authority than I, and I cannot better the pithy style of his narrative:—

I. Moses.—"*In the beginning God created the heaven and the earth.*"

Science.—Astronomical facts go to prove that other worlds were created before our own. It is therefore the right order to mention "The Heaven" first.

"*And the earth was without form, and void; and darkness was upon the face of the deep.*"

This is doubtless a description of the condition of matters before the creation of the earth.

II. Moses.—"*And God said, Let there be light.*"

Science.—There are strong reasons for believing that, before condensation into their present form, the Sun and Planets existed as a *luminous* nebula.

III. Moses.—"*And God said, Let there be a firmament.*" (Literally, "an expansion".)

Science.—On the cooling of the earth some of the gases

[1] Messrs. Cassell & Co., Ltd., 1881.

which surrounded it became mechanically and chemically combined to form air and water.

IV. Moses.—"*And God said, Let the dry land appear.*"

Science.—On further cooling great convulsions took place, which heaved up the rocks and raised them above the universal sea, forming mountains, islands, and continents.

V. Moses.—"*And God said, Let the earth bring forth grass.*"

The literal translation is: "Let the earth sprout forth sproutage". Notice, seeds are not mentioned.

Science.—The earliest forms of vegetable life were *not* grass, but Cryptogams, such as algæ, lichens, ferns, &c., which are propagated by spores and not by seeds. Dawson and Hooker have found such land plants in the Upper Silurian.

VI. Moses.—"*The herb yielding seed.*"

Science.—The lowest class of Phænogams, or flowering plants, such as the Conifers, are found in the succeeding strata. Dana mentions coniferous wood being found in the Lower Devonian.

VII. Moses.—"*And the fruit tree yielding fruit.*"

Science.—The fossils of a higher class of Phænogams, or flowering plants, bearing a low order of fruit, are found in the Middle Devonian and Carboniferous strata.

VIII. Moses.—"*And God said, Let there be lights in the firmament of heaven . . ., and let them be for signs, and for seasons, and for days, and years.*"

Science.—This does not describe the creation of the Sun and Moon, but their appointment to special offices; for previous to this period there had been no distinct seasons, nor had the days and years been hitherto accurately defined.

IX. Moses.—"*And God said, Let the waters bring forth*

abundantly (literally, 'swarm forth swarms') *the moving* (or creeping) *creature that hath life.*"

Science.—This evidently does not refer to the first dawn of animal life, for long before this period all the four great sub-kingdoms had been represented in the sea. But it seems to relate to a great increase in the number of the genera of the marine animals, and also to the increase of insects and of reptiles, both of sea and land.

X. Moses.—"*And fowl that may fly above the earth.*"

Science.—In the New Red Sandstone footprints of birds are found for the first time.

XI. Moses.—"*And God created great whales.*" (Should have been translated sea monsters.)

Science.—In the succeeding strata of the Lias monster marine saurians, such as the Ichthyosaurus and Pleiosaurus, are found.

XII. Moses.—"*And God made the beast of the earth after his kind.*"

Science.—Enormous beasts, such as the Dinotherium, Mastodon, &c., preceded the advent of cattle.

XIII. Moses.—"*And cattle after their kind.*"

Science.—Cattle, such as oxen and deer, appeared before man; some of them in the Post-Pleiocene period.

XIV. Moses.—"*The Lord God planted a garden . . . and out of the ground made the Lord God to grow every tree that is pleasant to the sight and good for food.*"

These passages are from the enlarged story (*Gen.* ii, 8, 9).

Science.—According to Agassiz, the principal flowers, fruit trees, and cereals appeared only a short time previous to the human race; and we find from *Gen.* i, 29, that they were existing "*upon the face of all the earth*" when man was created.

XV. Moses.—"*And God created man in his own image.*"

Science.—The highest and last-created form of animal life was Man.

You will want to know now what the geologists have to say upon this fascinating subject. To begin with, you must accustom yourself to a few alarming-looking words, though the geologist, like the Duchess in *Alice in Wonderland*, would probably say: "That's nothing to what I could say if I chose". Geologists divide the history of the earth into four eras, and each era is subdivided into periods. I do not suppose you will want to bother your heads with these names, but I must bring them before your notice just this once, and then, possibly, you will recognize them when you meet them again. The four geological eras, then, are: (1) Archæozoic or Eozoic, (2) Palæozoic, (3) Mesozoic, (4) Kainozoic. These eras refer to different ages of life on the earth. Nobody tries to classify the time before there was any kind of life, because such a task is really beyond the powers of the driest and stuffiest of scientists. We know that the separation of our earth from the parent nebula must have taken place, that it must have cooled and solidified, and that the land and water must have become distinct. But we do not concern ourselves with such remote events. It is from the evidence of extinct life that we collect our knowledge of the relative positions of land and water long, long ago. This evidence, as we shall see, points to many complete changes in the earth's surface.

Just once, then, let us go over these abominable names. I do not expect you to remember them, but if I set them down clearly for you you can always turn to this table for reference:—

Era.	Period.
Archæozoic or Eozoic, ...	Archæan. Torridonian.
Palæozoic, ...	Cambrian. Ordovician. Silurian. Devonian. Carboniferous. Permian.
Mesozoic, ...	Triassic. Jurassic. Cretaceous.
Kainozoic, ...	Eocene. Oligocene. Miocene. Pleiocene. Pleistocene.

A geological *group* comprises the rocks deposited in an era, while those deposited in a period are called a geological *system*.

The Archæozoic or Eozoic era—in plain English, Prehistoric—is the one we will consider first. The rocks found in this group are mostly what are known as crystalline schistose rocks. A schistose rock is one that has been pressed or beaten into a thin leaf lying between layers of some other rock—a kind of rocky sandwich in fact. Mica and talc are amongst the minerals of this formation. Archæan rocks compose the core of the Urals, Alps, Carpathians, and Pyrenees, and of mountain ranges in North and South America. They also occur in the north of Scotland, in India, and New Zealand. You will notice that this is the only era which has two names. The reason is that geologists cannot agree entirely

with regard to remains found in the Laurentian (North America) group of rocks. Some say the Laurentian group is crystalline limestone formed by the *Eozoon* (earliest life). In a subsequent chapter I shall tell you more about the Eozoon and his relations, the Foraminifera. Others say that foraminifera had nothing to do with it, and consequently call the era *Azoic* (no life).

The Palæozoic, or era of ancient life, represents a more interesting world. The Archæozoic age at best was a world of rocks and seas barren but for the Eozoon, supposing he existed, and a few primitive mosses. The Palæozoic era, however, produced a number of organisms. That highwayman of the seas, the shark, can trace his family tree as far back as the Silurian period. The waters swarmed with life, and many great amphibians made their appearance. Vegetation also developed abundantly. Graceful ferns and forests of giant conifers covered the land. There were a great many queer trees which we have never seen. Do you know the horse-tails which grow in marshy meadows? In the Devonian and Carboniferous systems they grew to a height of 30 feet, and geologists have given their fossils the name of Calamites. The Lepidodendrons were also great trees in those days, though now the only thing we have like them is the club-moss which grows on mountains. The roots of Lepidodendrons and of Sigillaria (*Stigmaria*) have been largely responsible for coal formations.

In the Mesozoic (or mediaeval) era life becomes still more interesting. The great reptiles which have

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ARCHÆAN ROCKS, NORTH OF KINGHORN, IN FIFESHIRE

These Primary rocks were volcanic in origin. They were formed by the cooling and consequent solidifying of molten minerals. The ripples on the sandstone to the left show that the sea must have existed there at one time.

such a fascination for all of us emerged from the waters. These monsters enjoyed existence with slightly varying forms throughout the era, but they were most abundant in the Jurassic period. A few small mammals came into being, and quite at the end of the era appeared the first flowers. Birds, with or without teeth, had become an established feature of the landscape.

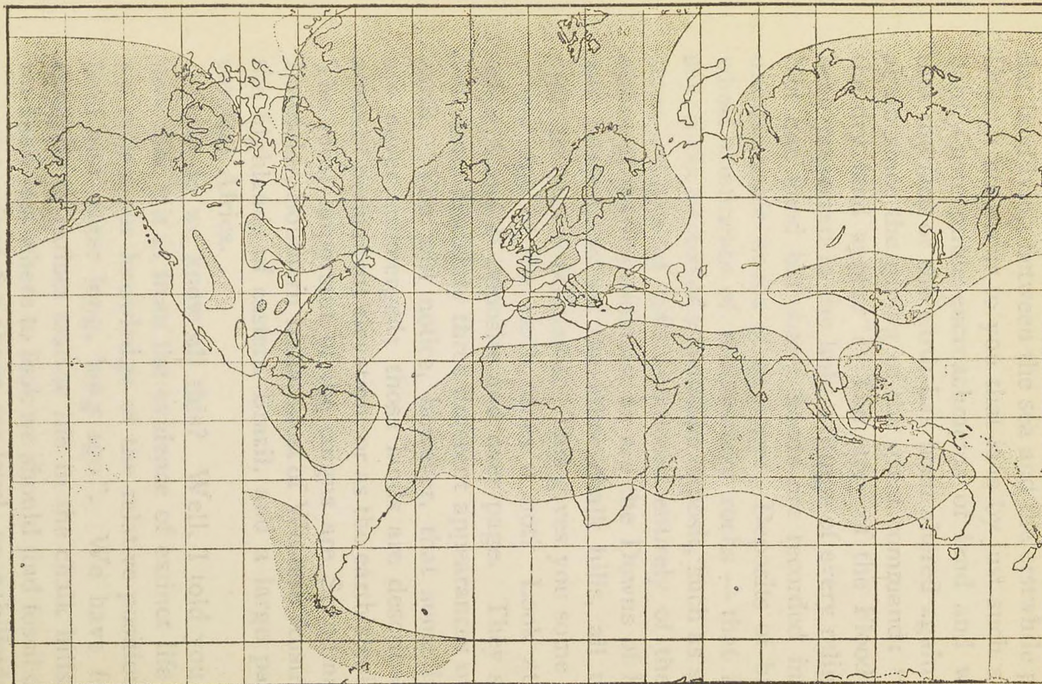
In the Kainozoic era we come to modern times—modern, that is, in a geological sense. This modern era, however, is old enough to admit of the entire history of the species Man. It also embraces the development of all the mammals and the total extinction of some of them, such as the mammoth and the giant sloth.

Well, you may say, this is all very fine, but how do we know it is true? How can anyone tell, for instance, whether the skeleton of a pterodactyl is in a Triassic rock or a Cambrian? After all, they are only names made up by a lot of old fogies. What is to prevent their forcing any old tale down our throats? To answer this question I shall have to refer you back to page 16, where I made the profound statement about the forces of segregation and disintegration. You had forgotten all about them? I thought you would have. You see, there is such a tremendous lot I could tell you of if I chose that it is really rather hard to get it all into one little chapter. I might (with the old fogies' help) fill the whole of this book with facts and theories concerning the making of the earth. Even then we should have left so much unsaid that I doubt whether we could

put it all in a dozen more books the size of this one. When we are studying astronomy we talk glibly about our tiny earth. It does seem tiny in comparison with Jupiter or Saturn, but when we begin to write its history we find there is a good deal of it to describe.

Segregation, then, is the gathering together of particles in a group away from other particles. Disintegration is the breaking-up of the segregated mass. Segregation was at work binding together the original nebula. Disintegration was at work when the fragments which form our solar system flew off. Segregation solidified our land. Without the help of this force it might have remained of a muddy, semi-fluid consistency. Thus we have our globe divided into two main divisions, land and water. But our friends did not consider their work finished. Disintegration set to work immediately on the newly formed land, and began to wear it away again. Rain, wind, heat and cold scratched and pricked and scraped to produce that abomination of the modern housewife—dust. Then the wind took the dust and carried it away until some crevice caught it. Segregation turned up again at this point, and after a few ages had passed the crevice grew to be a hillock. In the same way a rocky prominence will have become a hollow. But the ocean was the most powerful agent employed by D. & S. Bros. You read to-day in the paper of the dangers of coast erosion, and how so many square yards of land have been washed away from the Suffolk coast in three years. Then you go to Rye or to Sandwich and see the miles of

MAP A



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DISTRIBUTION OF LAND AND SEA—DEVONIAN (SECOND CONTINENTAL) PERIOD

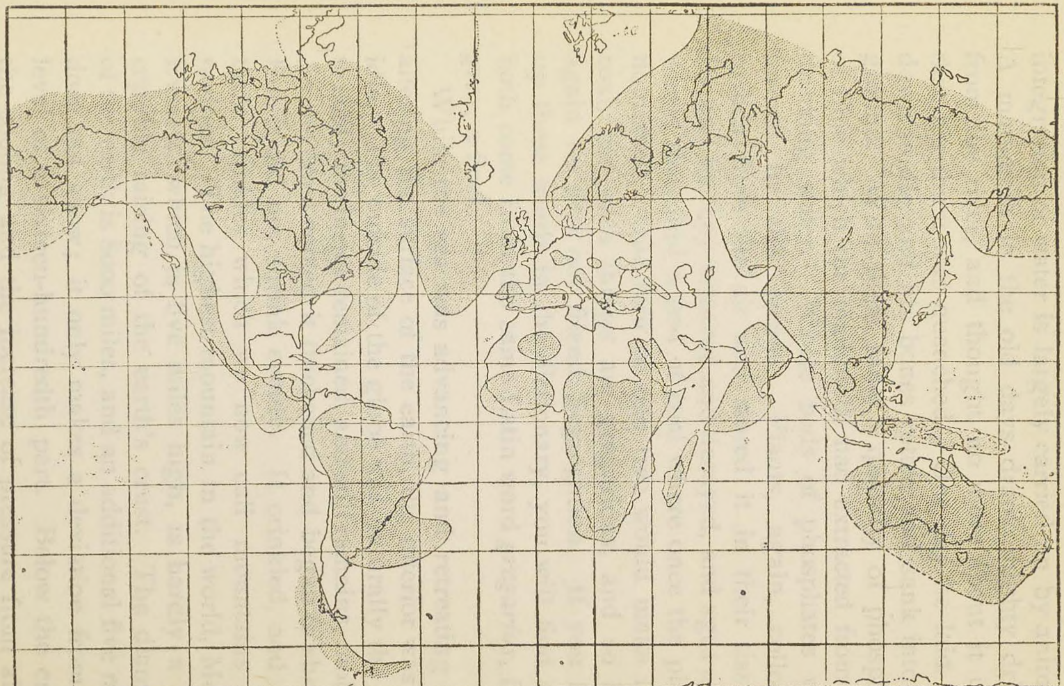
The shaded portions show the positions and approximate boundaries of the chief land areas. (After De Lapparent.)

flat land lying between the sea and the erstwhile port. Does it not occur to you that it is by just such slow, hardly-perceptible encroachments of land and water that the face of the earth has been altered again and again since the giving of the great command: "Let the dry land appear"? The story of the Flood has been preserved in the holy writings of every religion. Not one flood but many floods are recorded in the unmistakable words of geology. Deposits of brine, whole continents of sedimentary rocks — that is to say, rocks formed of a sand-like deposit, such as sandstone—ranges of hills composed entirely of the remains of marine animals, as are the Downs of Kent and Sussex and all the other chalk hills, all these point to marine influence. This gives you some idea of the age of the earth, does it not? Look at the maps A and B opposite and over page. They show you quite distinctly three different appearances of the earth. You will notice, however, that some lands are never submerged; those lands are described as areas of permanent elevation, or as the earth's coigns. The most important of the coigns are Scandinavia, Labrador, Southern India, most of Western Australia, the highlands of eastern Brazil, and a large part of tropical Africa.

How do we know all this? Well, I told you just now that "it is from the evidence of extinct life that we collect our knowledge of the relative positions of land and water long, long ago". We have found evidence of extinct marine life in the chalk hills. If we knew just where to look we should find fossil deep-sea ooze raised far above sea-level, on a hillside for

instance. We cannot go grovelling on the floor of the ocean for remains of land animals, and, indeed, the weight of the ocean would soon crush such remains to powder, so the zoologist comes to our rescue. Now, says he, we find the family of lizards known as geckos distributed throughout South and Central America, Africa, Arabia, Southern Europe, Southern Asia, and Australasia; butterflies of the family Acræidæ occupy practically the same position, though they do not extend so far north. There are many other zoological links between the continents. We never find them spreading northwards, but since they occupy the whole of the southern hemisphere, it is reasonable to suppose that they travelled by land from one point to another. This vast southern continent has been given the name of Gondwanaland. The whole of Eastern Asia is Angaraland, while a great northern continent embracing east of North America, Scandinavia, and the Arctic regions is called Arctis.

Segregation thus evinces its influence on animals. Countless millions of organisms must have been swarming near together in the sea for their fossil remains to be deposited together. We speak of birds and animals as gregarious when they live together in flocks. Man, too, is a gregarious animal. He thinks it is because he likes company and because he finds it convenient to live in a town, but the reason is deeper than that. No creature ever does what it likes. Man, as well as sheep and starlings, must obey the law of segregation, just as his digestive apparatus obeys the law of disintegration. The dis-



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DISTRIBUTION OF LAND AND SEA DURING THE GREAT CRETACEOUS SUBMERGENCE

The shaded portions represent land as in Map A. (After De Lapparent.)

integration of water is largely carried on by animals. A mammoth in the old days drank mighty drinks from the river, and thought no more about it than that his thirst was quenched. One day he laid him down to die, and his bones rotted and sank into the ground. With them sank a quantity of phosphate of lime which the mammoth had extracted from his drinking water. Whole beds of phosphates were formed by this means. Plants, again, collected carbon from the air and stored it in their tissues. By and by they withered and decayed, and ages afterwards men find a bed of coal where once the plants flourished. One fern or one tree would make little coal, but such things are gregarious, and so here again we find our friend Segregation. If you look up these words in the dictionary, you will find they both come from the same Latin word *gregarius*, from *grex*, a flock.

While the sea was advancing and retreating and altering the surface of the earth, the interior was not idle. The outside of the globe was naturally the first to cool; the inside remained, and still remains, molten. As the crust cooled it thickened and began to shrink. But it did not shrink evenly. It crinkled, and it is these crinkles which we now call mountains and ravines. The highest mountain in the world, Mount Everest, which is five miles high, is hardly a perceptible raising of the earth's crust. The diameter of the earth is 8000 miles, and an additional five miles does not show; it only makes a deviation from the level of a sixteen-hundredth part. Below the crust, the cooling and the increase of pressure from above

combined to form rocks. Rocks that are formed in this manner (that is to say, by the action of heat) are termed igneous rocks. The igneous rocks are of two chief kinds: volcanic, when they are discharged in a molten state and solidify on the surface; and plutonic, when they are formed far below the surface. The shrinking crust thickened in some places, leaving others very thin. The thickened parts tended to sink and press heavily on the mass beneath, which thus was pushed towards the thin places. After a time, generally when an accumulation of water had been vaporized by internal heat, the thin place would be pierced by the intruding plutonic rocks. Then steam, gases, and molten rocks would burst through, and a fully-fledged volcanic eruption would ensue. The plutonic rocks would be scattered all around, while the molten rocks would spread out over the surrounding country. In time a hill would be built up, becoming, if nothing interfered, a mountain in due course. From the vent, along with the steam and rocks, a vast volume of water would be discharged. This water, which had come boiling up from the centre of the earth, carried with it metals and mineral substances in solution. When the water had cooled the metal would solidify and remain embedded in the volcanic rocks. The changes that are achieved by the internal heat of the earth, such as earthquakes and volcanic eruptions, are referred to as *hypogene action*, while those which are induced by superficial agents are called the results of *epigene action*. Hypogene action is the quicker of the two. Listen to this account of an earthquake in the Andes, given by

Mr. A. E. Pratt in an article in the *Wide World Magazine* for January, 1914, entitled "Across the Andes and Down the Amazon":—

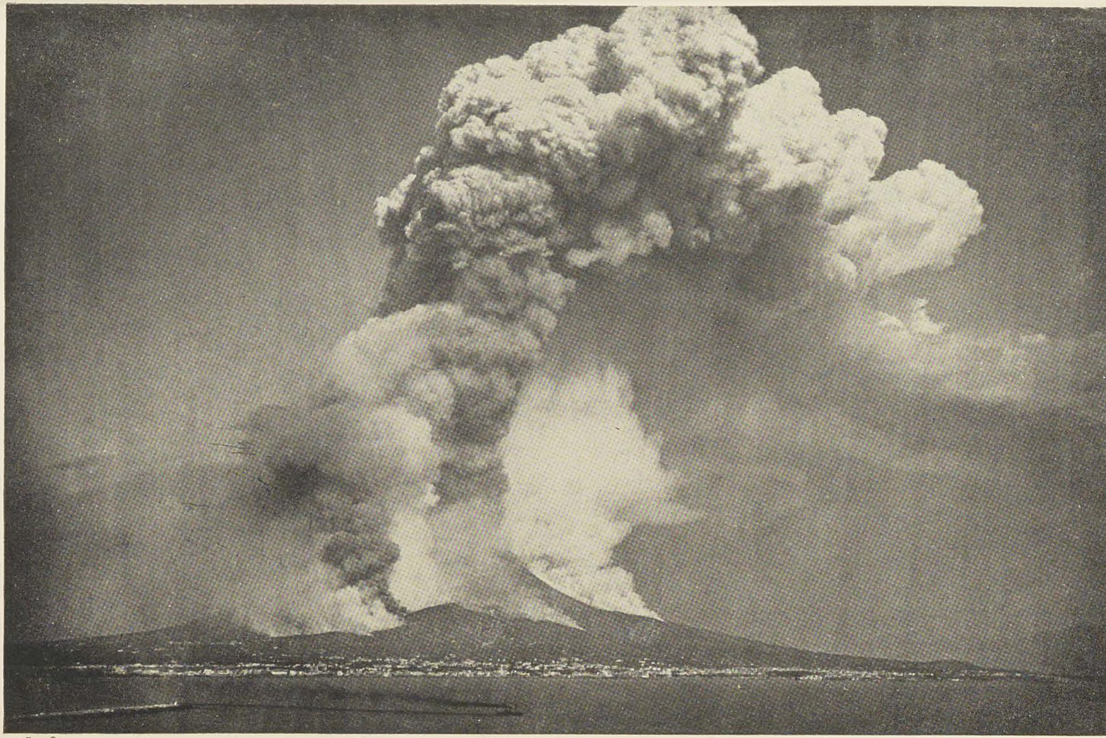
"One morning, just after we had risen and were preparing our frugal breakfast, we were startled by a rumbling noise, followed immediately by the quaking of the earth. There is nothing which so appals a man, makes him realize so keenly the might of Nature and his own utter powerlessness, as an earthquake. One feels what one really is—just a microscopic atom in the scheme of things.

"On that memorable morning it seemed as if the ridge on which we were camped would fall bodily into the valley below. It was trembling violently; in fact, the whole stupendous Cordillera was rocking, and as we watched in fascinated, petrified silence, a great part of the mountain on the opposite side of the valley broke away and crashed headlong down, carrying everything in its train. All around us great forest trees were falling, and masses of loose earth and stones, tearing down, blocked up the road, while crevasses were formed in many places.

"I think we felt the effects of the shock more afterwards, for at the time our powers of sensation were numbed, save for a terrifying realization of utter helplessness. We heard later that a river on the borders of Ecuador had been dammed up by a fallen mountain, and that the church at Huancabamba had lost its tower. The town itself had a distinct crack formed right through the centre of it, but beyond this it did not suffer. Puira, however, was completely destroyed. We understood that the damage to house property

alone exceeded six million *soles* of Peruvian silver—well over half a million sterling. . . ."

By this earthquake the face of the country was altered to an enormous extent in the space of one minute. Epigene action would have taken ages to perform the same amount of destruction. Fortunately such catastrophes are comparatively rare. There are between twenty and thirty earthquakes every day—often more—but few of them do any damage. The causes of earthquake are obscure, and many theories have been advanced, none of which seems completely to cover the phenomenon. We know that deep down in the earth there must be cavities. If the roof of one of these were to collapse, the crust above, of course, would collapse too. Strata of rock subjected to any great pressure or tension might snap, causing a fissure. Or, as many earthquakes originate beneath the sea, a frequent cause may be found in the water finding its way into the heated regions in the interior and flashing into steam. Others are connected with volcanic disturbances, and may be traced to the exploding of gases. A more dreadful occurrence even than an earthquake is a sea wave. An earth wave, rising under the sea, passes along to the shore and proceeds inland. As it leaves the sea, however, the water, which has been forced upwards by the earth wave, falls back, and, gathering volume, returns as a "great sea wave". It may reach the height of 80 or 100 feet. The greatest on record broke on Cape Lopatka in 1737, and is said to have been over 200 feet high. Many large portions of the earth have been permanently raised or depressed by these move-



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AN ERUPTION OF MOUNT VESUVIUS

So long as a volcano is active it is liable to injure itself. Vesuvius lost 800 feet of its cone during the eruption of 1822. The tenth eruption of the Japanese volcano Brandaisan in 1888 blew 1,587,000,000 cubic yards of rock fom the top of the mountain.

ments, and it is probable that they were instrumental in alternating the positions of continents and oceans.

Nature, however, is never satisfied. As soon as she has built up a volcanic hill she sets to work to wear it down again. Epigene and hypogene action may combine to help her, but often epigene has all the work to do. When we go to Edinburgh we gaze at Arthur's Seat and think what a mighty lump it is. It is only a remnant, however, of a very much mightier lump. A stupendous volcano, of which Arthur's seat is only the rocky core, once raged there. So long as the volcano is active it is liable to injure itself. Streams of lava, carrying fragments of rock, may score the sides of the mountain, while great explosions often carry away part of the crater. Etna and Vesuvius have been altered in this way several times. Vesuvius lost 800 feet of its cone during the eruption of 1822. The terrible eruption of the Japanese volcano Bandaisan in 1888 was instrumental in blowing 1,587,000,000 cubic yards of rock from the top of the mountain. From an impersonal point of view, one of the most disastrous of recent volcanic eruptions was that of Tarawera, in New Zealand, in 1886. A great portion of the south-western slope of the mountain entirely disappeared, leaving a depression 2000 feet long, 600 feet wide, and reaching a depth of 800 feet. Worse than this, the Pink and White Terraces, one of the wonders of the world, were buried completely beneath the debris and dust of the shattered volcano. When the fire and fury have exhausted themselves and the volcano becomes extinct, springs of cold water frequently start from

the side of the mountain. These springs may be charged with mineral matter and with carbonic acid, in which case they are active agents of denudation. From the first hour of its birth, moreover, the volcano has to combat the influences of rain and wind. But so long as the volcano is active it can hold its own against such slow processes. Since 1796 an island several thousand feet high and 3 miles in circumference, has been formed by a volcano in the North Pacific Ocean.

The nature of the lava thrown up a volcano determines the shape of the crater. Some lavas are very viscous and solidify immediately round the summit of the crater. This results in a steep, abrupt cone. Lava of this kind sometimes wells up and fills the crater, and this explains why, occasionally, extinct volcanoes have no vent. Lava which is ejected in a more liquid form flows away and spreads itself out before consolidating, thus building up a flattened mountain. The volcanoes of Hawaii are of this formation. Etna and Vesuvius are composite cones—that is to say, they are built up partly of lava and partly of rocky fragments. The volcanoes of Java are what is called the explosive type. They discharge no lava, but quantities of loose rocks and stones.

With the development of mountains and volcanoes, the game of constructing the map became more intricate than ever. Epigene action continued unbrokenly, but sun heat was reinforced by volcanic heat, and the action of cold was surpassed by the action of glaciers. These came grinding down the

mountain sides, cutting and scoring the rocks. Whenever you see a lump of rock with cuts and scratches on an otherwise straight, smooth surface, you may know it has been under a glacier. The rivers, too, became far more energetic. They were swollen by mountain streams and by melting mountain snows. Instead of winding placidly across the plain, they came tumbling into the valley from a great height, and the farther they fell the farther they fell. This sounds like an answer to "Why is an oven when it is hot?" or some nonsense of that kind, but it is really quite sensible. You know a river carves out its own bed. Ever such a little waterfall will gradually become deeper if there is a free passage for the stream, so that the deeper the drop becomes the more force will the falling water have and the faster it will wear away the rock below. But while the glacier and mountain stream were busy disintegrating, the river was busy segregating. Masses of sand and silt collected on the river bank preparing fertile meadows for man to cultivate—for the coming of man was still in the dim future. This erosion of rocks by the elements forms a particular kind of mountain. When all the soft rock has been worn away by the river and the glacier, there will remain a core of hard rock upon which their efforts have no effect. This hard core is left standing alone, like the last rose of summer, watching all its lovely companions being slowly ground to powder and carried away. Thousands of years pass, and the rock becomes first a boulder, then a cliff, then a hill, and then a solitary mountain in the midst of the plain, or a range of mountains stretching

across a flat country. This kind of formation makes a Residual mountain—that is to say, a mountain that has been left behind. Mountains which are made simply by the crinkling of the earth's crust in cooling, such as the Alps, are called Fold mountains. Block mountains are those formed by a tilting of blocks of the earth's crust, or by the depression of adjoining blocks. But all these motions are gradual. The most impressive mountains of the world are those of volcanic origin.

It is believed by geologists that there has never been a time when volcanoes were completely dormant, but there can be no doubt that periods of extraordinary activity alternated with periods of comparative torpor. The Archæozoic era suffered tremendous upheavals. The Cambrian was a period of few volcanic eruptions, followed by the stormy Ordovician. The Silurian was almost entirely dormant, quite pastoral, in fact, giving up its time to the deposit of sediments. The Devonian was marked again by internal dissensions, while the Carboniferous, except in southern Scotland, was quiet in the beginning and stormy at the end. Its violence continued all through the Permian.

In the Eocene period Nature turned her attention to the south-east of England. London clay and the chalk hills had just been successfully made when the good lady's attention was drawn off elsewhere. Africa, India, Australia, and America combined in a *feu de joie*, and as a fitting commemoration of the happy event the Western Isles of Scotland crowned themselves with volcanoes. Most of the mountain systems in England and Wales were built up in Cambrian

and Ordovician times, while Scotland's mountains dated from the Carboniferous and Permian periods.

We cannot conceive the immensity of the outburst which built up even such a small mountain as Cader Idris. Cader is only 3000 feet high, but his bulk in proportion is enormous. We can have no idea of the ceaseless activity which must have been at work for years, scattering rocks and boulders to extraordinary distances, pouring out streams of lava and of water laden with minerals in solution. On this mountain, and on Snowdon, you still may see craters; extinct now for many a long year, but remaining as sinister, unfathomable lakes. Yet both these mountains are insignificant examples of volcanic power compared with the giants in America and the East Indies. Eye-witnesses have preserved the story of the eruption of Jorullo, which occurred about a hundred and fifty years ago. This was, as things go, quite a small eruption, but it will serve as an illustration of the course of such upheavals:—

In Mexico there lived a gentleman named Don Pedro di Jorullo. He occupied an exceedingly prosperous farm, watered by two small rivers, Cuitimba and San Pedro, and fringed by a chain of basalt mountains. Basalt, you must know, is a rock formed by volcanic action. In the month of June, 1759, a number of earthquake shocks were felt, accompanied by strange noises underground. These alarms continued for several weeks and then ceased. No one took any real notice of them. On the night of the 28th September, however, the noises recommenced with redoubled vigour. The earth trembled and

quaked, and all the Indian servants left their beds and ran in terror to the mountains. From this place of safety they witnessed an awful scene. They saw the whole of their master's farm—a tract of land measuring about 4 square miles—raised up above the plain. What had been level ground became a precipitous hill, about thirty-nine feet high at the edges, and over five hundred feet high at the crown. The whole country was illuminated by volcanic flames, while clouds of ashes and white-hot stones were flung far and wide. The intervening ground began to sway and wave like a stormy sea. The two little rivers disappeared into great chasms, from which, in consequence, appeared clouds of steam. Small cones now began to rise all over the surface. From their summits dense vapour and steam were emitted, and to this day a sound as of water boiling is heard within them. From amongst these cones six large hills were thrown up, the largest, which is now the volcano of Jorullo, being 1600 feet high. Violent eruption continued for four months, during which time ashes and dust were thrown to a distance of 150 miles.

Dust from the craters of Etna and Vesuvius has been found on the roofs of houses in Tripoli, while the dust from the outburst of Krakatoa was carried to spots 885 miles away. This, indeed, was undeniably the greatest upheaval of modern times. Hundreds of thousands of lives were lost. The eruption began early in the summer of 1883. The Dutch Government sent a party of scientists, amongst whom was a gentleman named Van Gestel, to take observations in May. The volcano was then in a state of great

activity, and the would-be observers found their position precarious. The column of flame issuing from the crater was visible 50 miles away. At intervals great masses of rock were thrown up 300 or 400 feet, exploding at that height with a loud noise, while a torrent of molten sulphur poured down the mountain side. The scientists pluckily attempted to climb the mountain, but they found it impossible to approach the crater. The flame, which for 300 feet of its height was of a blinding whiteness, was a mile and a half in diameter. At a distance of half a mile the heat roasted and cracked the skin, and as the scientists retraced their steps to the steamer they found their former footprints glowing with subterranean fire. We may be sure that they were thankful to sail away from so dangerous a neighbourhood.

This state of things continued for months, and ceased to occupy the attention of the world. Mr. Van Gestel, however, remained at Anjer, thirty miles from Krakatoa, awaiting events. On the fateful 12th of August he was placidly engaged in admiring the view while taking his morning coffee. Suddenly he noticed that all the little boats lying at anchor in the bay were moving in one direction, and as he watched they disappeared. He ran higher up the hill and looked out to sea.

[1] "Instantly a great glare of fire right in the midst of water caught my eyes, and all the way across the bay and the strait, and in a straight line of flame to the very Island of Krakatoa itself, the bottom of the sea seemed to have cracked open, so that the sub-

[1] *Cosmopolitan Magazine.*

terranean fires were belching forth. On either side of this wall of flames, down into this subaqueous chasm, the waters of the strait were pouring with a tremendous hissing sound, which seemed at every moment as if the flames would be extinguished; but they were not. There were twin cataracts, and between the two cataracts rose a great crackling wall of fire hemmed in by clouds of steam of the same cotton-like appearance which I have spoken of. It was in this abyss that the fishing-boats were disappearing even as I looked, whirling down the hissing precipice, the roar of which was already calling out excited crowds in the city of Anjer at my feet."

As Mr. Van Gestel stood fascinated, watching this terrible phenomenon, he was stunned by the sound of an awful explosion. In the instant of his unconsciousness the whole world plunged into darkness.

"Through this darkness, which was pierced by distant cries and groans, the falling of heavy bodies and the creaking disruption of masses of brick and timber, most of all the roaring and crashing of breakers on the ocean, were audible. The city of Anjer, with all its 60,000 people in and about it, had been blotted out, and if any living being save myself remained I did not find it out then. One of those deafening explosions followed another as some new submerged area was suddenly heaved up by the volcanic fire below and the sea admitted to the hollow depths where that fire had raged in vain for centuries."

We cannot be surprised that Mr. Van Gestel was

frightened by the sound of the sea hurling itself upon the land, and that he turned and ran, not knowing, in the pitch blackness, where he went, nor caring so long as it was upwards. At last he saw a little house standing by the roadside. He rushed in, hoping to shelter from the intense, oppressive heat, only to rush out again immediately. He had seen a dead woman, and little blue flames flickering through the floor. On and on he ran like one possessed until at five o'clock in the afternoon he reached the city of Serang. But his mind was quite unhinged by his fearful experience, and for two days he knew nothing. When he recovered his reason he tried to return to Anjer. Alas! the city lay 100 feet under the sea. Every living thing had been destroyed. Not a blade of grass or green leaf remained. The noise of the explosion was heard more than 2000 miles away, and the darkness was experienced at a distance of 600 miles, while the great tidal wave careered right round the globe, making itself felt in every port. Ask your father whether he remembers the glorious sunsets of 1883 and the two following years. The splendour of those sunsets was due to the fine dust flung into the upper reaches of the atmosphere by Krakatoa.

This, then, is a very crude, incomplete summary of the world's history. First the blazing incandescent globe detached from the parent nebula. In this globe the elements which afterwards cooled and formed the land and water were in a gaseous or molten state. Then, when the globe had cooled sufficiently to separate into its two component parts, eternity of change and alternation. Never any rest, any completeness.

Spring, summer, autumn, and winter follow one another in our own short lives, each doing its part in the work of building up and breaking down the world. Magnify these seasons by a million and we have an imperfect conception of the geological seasons; the alternation of heat and cold, of flood and drought, which have had so wide an influence in preparing the earth for us to live upon. But if you ask me *why* or *how* these results have been achieved I must confess that no human answer can be found. We must believe—we have no choice—that an omnipotent Creator framed the natural laws and formed the world in strict accordance with them. There has been no miracle about it. Each phase naturally and perfectly has followed its predecessor. The development of all things—rocks, plants, animal life—has been successive and inevitable. And in Nature there is nothing ugly or useless. Let us, then, bring to our study of the materials of the earth a loving wonder and reverence for the Power which has caused them to be formed for our use.

CHAPTER II

King Coal

HAVING made the world as a whole we must now spend an hour or two in studying more particularly some of the substances which compose it, or which lie hidden in clefts and crannies of the great geological systems. I think you will agree with me that coal ought to occupy our first attention, for without coal and the wonderful processes it makes possible many of the treasures of earth would be useless to us. Indeed, it is very doubtful if civilization would have advanced one-half as quickly if it had had no coal to help it. We should have progressed at walking pace only instead of at the speed of an express train; in fact we should be little "forrader" than our forefathers, the ancient Britons. We may take to ourselves the credit of being the first European nation to use coal to any great extent. Perhaps our supplies were more easy of access than those of other countries. Certain it is that our consumption of coal has been increasing ever since 852 A.D. In the thirteenth century we learn that the citizens of London protested against the use of coal on the ground that it was injurious to health. It was prohibited accordingly, but not for long. Wood was so costly that the industries

suffered, and eventually the Londoners were obliged to capitulate.

Coal came back into favour and has kept its place till the present time. The future alone will show whether we shall live to see it ousted by some other power. A substitute will have to be found sooner or later, for, one of these next days, as my Welsh friends say, we shall exhaust our coal supplies. You must not believe people who tell you that coal is still in course of formation. Such a thing is impossible, as we shall see.

Picture to yourselves the world in those early days when the coal measures of the Carboniferous System were being made. There were no men, no birds, no butterflies, no cattle. The waters swarmed with life, and as the world waxed older amphibians made their appearance. The only flowers were the insignificant forms of the conifers. For the most part the world was a succession of swampy islands and shallow seas. There were no great continents and no vast, unfathomable oceans. The swamps were covered with jungles of trees such as we do not see to-day.

Some of these bore a family resemblance to our monkey-puzzles, others to our pines and firs. A great family, the Calamites, are represented by the mare's-tails that grow in our hedgerows, only the Calamites were 30 feet high. The Lycopodiaceæ, which grew to a height of 70 or 80 feet, with a diameter of 3 feet, creep on the ground in modern times and are called club-mosses. Very beautiful trees were the Sphenophylla. In shape they re-

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PREPARED FOR THE PITHEAD

A group of miners who have just received their safety-lamps and are setting out for the pithead to descend into a coal-mine. There are in the United Kingdom over 800,000 miners, and on an average they bring up about 264,000,000 tons of coal each year.

sembled our Lombardy Poplars, but they had large toothed leaves, veined like fern leaves. But the great beauty of these jungles was the ferns. You have all seen tree-ferns, I expect. Many of you may have them in your gardens, and you know how tenderly they are cared for at the least approach of frost. Well, imagine those tree-ferns magnified ten or twelve times, growing wild with the greatest freedom. Smaller ferns clustered round their roots and made a green carpet. You must bear in mind that at the first dawn of vegetable life the world was not a sunny place. A belt of mist encircled it and it was warm, not with the sun's rays but by its own internal heat. So it is probable that there were plenty of plants growing in the darkest shade of the jungle.

If we want to make an accurate picture of the coal forests we must imagine them to be continually sinking. It took but a day, geologically speaking, for a forest to spring up, mature, slowly sink into the marsh, and finally disappear under a flood or an encroachment of the sea. The waters brought with them mud and silt, and the forest compacted and settled itself underground. Then by some earth-movement the swamp may have been raised again or the water may have subsided, leaving an area of bare mud. Immediately another forest would spring up, to occupy the soil for a space and then in its turn to be overwhelmed.

By and by changes became obvious. The vegetation altered and seemed less vigorous, while the land afforded a hunting ground to horrible amphibious monsters. The only true land animals of the car-

boniferous age were a few insects of the cockchafer and locust kind.

The temperature of the world throughout this, which we may call the vegetable age, must have been warm and moist. We sometimes hear it said that the coal forests flourished in a tropical climate, but we must remember that climate, as we understand it, did not exist in those days. Remains of the same *flora* are found in every quarter of the globe. The point at which the two ages diverge is the composition of atmosphere. You know, I hope, what sort of stuff you are breathing, or should be breathing if you have your windows open, at this very minute. You may describe it roughly as containing four parts of nitrogen to one of oxygen, a very small quantity of carbonic acid, and minute quantities of some rare elements that have not long been isolated. But if you were to stop up all the air-holes in your room and invite twenty others to spend the afternoon with you, you would be going the right way to reconstruct the atmosphere of the coal age. In other words, the trees of the coal forests breathed an air loaded with carbon dioxide. Oxygen was scarce.

Vast areas of land were covered with gigantic trees which very quickly attained maturity. Then, their day over, they succumbed to circumstances. But they did not decay. Oxygen is necessary to the process of decay. They lay, or stood, in their clayey graves, fermenting a little, and always, by reason of the pressure to which they were subjected, tending to compact and harden and to concentrate their

stores of carbon. We are told that coal deposits represent as little as one-sixteenth of the original vegetable mass.

This is known as the "growth *in situ*" theory of coal formation—that is to say, the theory which holds that the carboniferous forests flourished in the places where the coal is now found: but it is not the only one advanced. In some coal-fields seams of coal are found between strata of sedimentary rocks, and many geologists are of opinion that the vast quantities of silt necessary to form these rocks could only have been deposited by the sea. Indeed, we know that many beds of coal must have lain under the sea at some time or another because fossils of marine animals are often found in coal-mines. Those who cling to the growth-*in-situ* theory maintain that the sea advanced and covered the place where the forest grew and afterwards retreated, allowing a new forest to spring up in the silt. Those who prefer the "Drift" theory say: "No, it was not that way. The whole forest was carried bit by bit to the sea by rivers, and the beds of carboniferous matter and silt congregated in estuaries." However that may be, we can be quite sure that the sea, or some great lake, had a part to play.

We cannot estimate with any accuracy the number of years which have passed since these carboniferous forests first appeared on the earth, but we know from the differences in coal that deposits were formed in successive ages. We can trace the story of coal backwards through several stages. In most hill and moorland districts there are stretches of bog. Nature has

either forgotten to insert drain-pipes, or they have become stopped up in some way. The soil of the bog is black and slimy, but on its edges and in the ridges traversing it the ground is dark-brown and firm. You can cut it into clean squares with a spade, and if you take these blocks home and dry them you will find that they will keep your fire alight for a long time. These, then, are the two youngest forms of coal which we can recognize—bogland and peat. There is a wide gap between peat and the next distinct coal form. This is *lignite*, which still has a fibrous or turfy structure, wherein fragments of bark and leaves still may be discerned. Lignite is rare in England, but deposits are found near Exeter. It is believed to be the remains of forests of a kind of Sequoia, the tree that attains such huge proportions in California. *Brown-coal* may be regarded as the next degree, for though by this time the woody structure has disappeared it is by no means identical with true coal. *Cannel-coal* and its near relations *splint* and *parrot* belong to the succeeding age, as does also the curious substance known as *Torbanite*, or boghead. This has all the useful properties of coal but does not resemble it outwardly. Indeed, its un-coal-like appearance led to a lawsuit in Edinburgh. The owners of a mine at Torbanehill claimed that their tenants had no right to mine minerals other than coal, and that boghead, which this mine was producing, was not coal. The court, however, decided that boghead, or Torbanite as it had come to be called, was a coal.

Now we come to the true coal, called by some authorities *bituminous* coal and by others *humic*

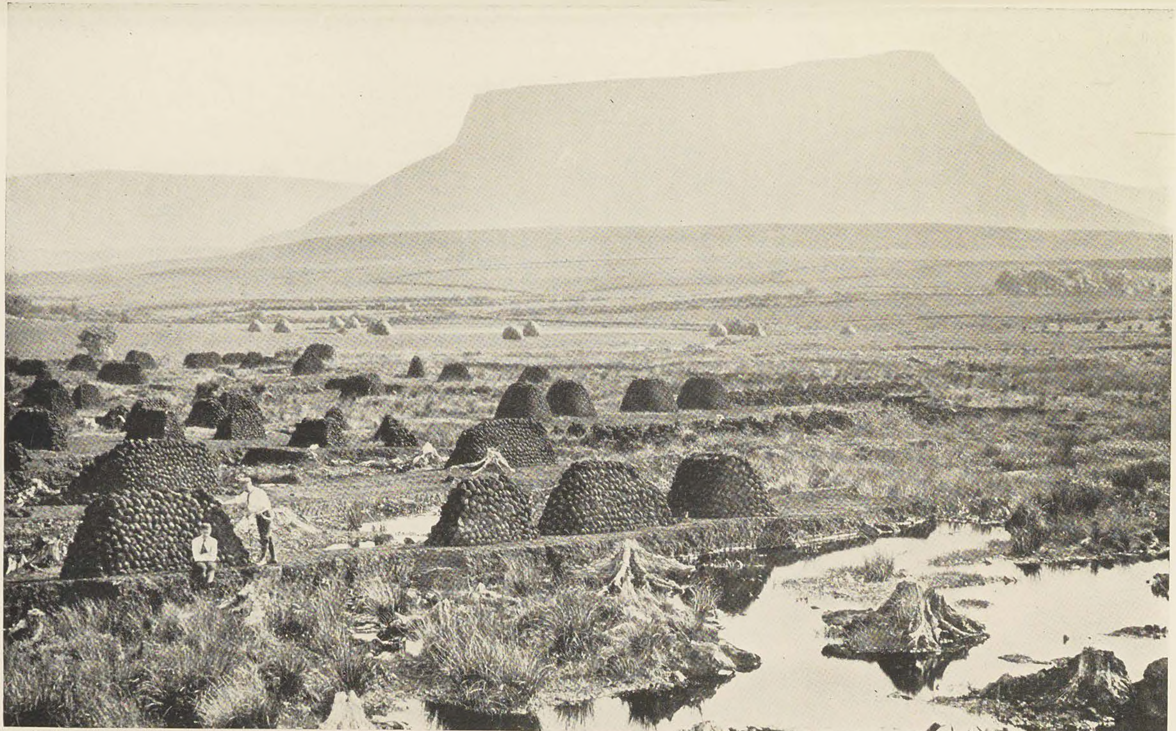

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Photo. R. Welch

A TURF BOG AT GRANGE, SLIGO

We can trace the story of coal backwards through several stages. Bogland and peat are the two earliest forms of coal. There is a wide gap between peat and the next distinct coal form, lignite, which still has a fibrous or turfy structure and in which fragments of bark and leaves may be discerned.

coal. This is the coal we use in our houses. You know it very well by sight, but it will do you no harm to examine it a little more closely. You cannot touch it without blacking your fingers, whereas you can handle cannel-coal without reaping so much as a smut. But your hands will wash, and if you search diligently enough you may find a lump of coal with a dull streak in it. This dull layer is worth pulling to pieces, for you may happen to find unmistakable bits of leaf or wood.

If your father is sufficiently up-to-date to have installed anthracite stoves in his house you will be able to compare the two coals. Anthracite is quite different from the humic coal. It does not kindle quickly, and it smoulders rather than burns, giving little flame and smoke but a great deal of heat. There are never any little shoots of gassy flame from anthracite coal, and the reason for this is very interesting. The gas has all been expelled long before the anthracite is taken from its bed in the earth. At one time or another this coal has been subjected to great heat from the earth's furnaces and the gas has escaped. There were no gas companies to appropriate it, and probably it issued from some crater in the form of flame. The coal that it left behind is a most valuable substance. It has no equal among solid fuels for marine purposes since, bulk for bulk, it gives more heat than any other coal. The absence of smoke is another point in its favour. Smoke means dirt, and dirt has to be cleared away, so that anthracite is a labour saver. Large quantities of slack of anthracite, known locally as culm, are found in some

mines, and geologists say that this is the result of tremendous movements in the earth which have jarred and crushed entire seams of coal to powder.

We must be quite clear in our minds as to the significance of these different names for coal. It is not precisely a question of age nor yet one of raw material. I mean, though I have told you that lignite, for instance, is the product of a particular species of tree, and that brown-coal is older than lignite, we must look for other qualities before we definitely classify the different rocks. It is conceivable that extraordinary pressure might "age" a coal before its time, while pressure or heat below the average might have the effect of retarding its maturity. Besides, commercially speaking, the age of a coal makes no difference. The engineer wants a coal that will burn, not one with a pretty story attached to its childhood and youth. The thing that makes coal burn must be contained in it now, and that particular thing is carbon.

Now you see why it is that we cannot expect new coal-fields to form to-day. The trees and other vegetable growths which made our present coal resources breathed an atmosphere containing inexhaustible stores of carbon dioxide. The carbon they retained and concentrated for our future use, a feat which the present forests are unable to achieve from sheer lack of material. Wood contains only 50 per cent of carbon; peat, not more than 60 per cent; humic coal, from 80 to 92 per cent, while anthracite attains a percentage of 97. Curiously enough we notice that the coals with a low percentage of carbon kindle quickly. "Cannel"

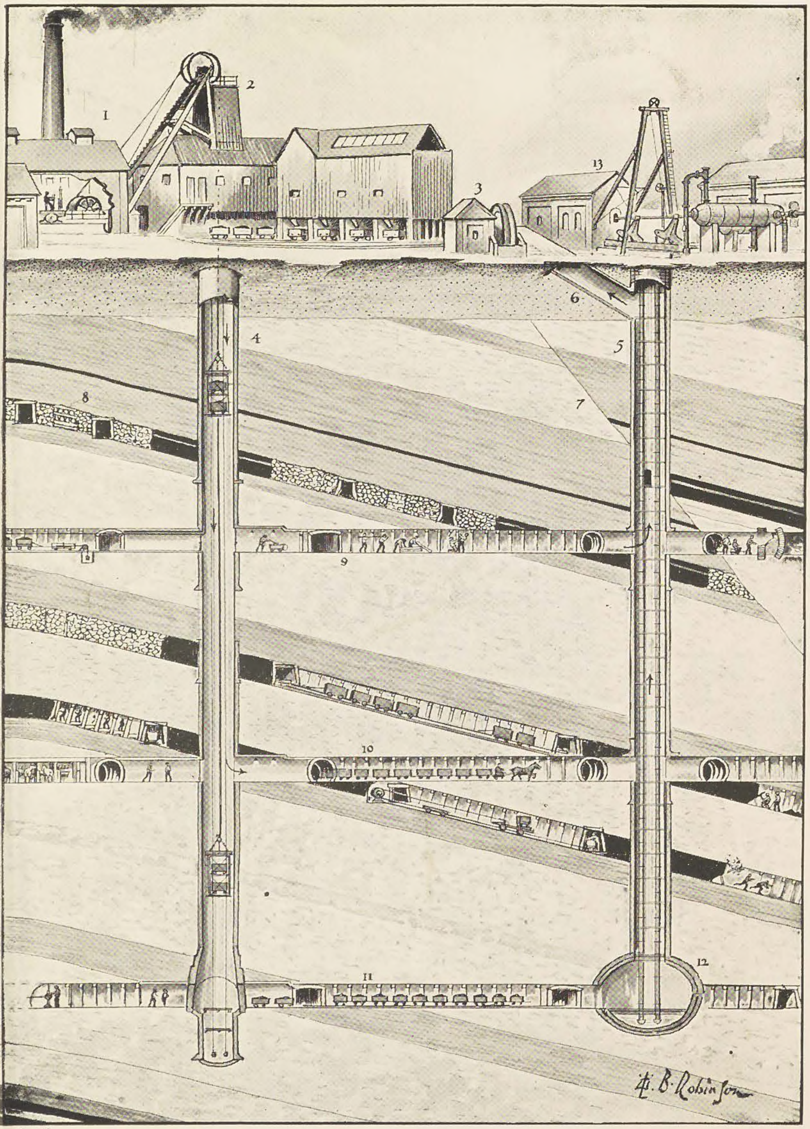
coal is so called because it flares like a candle. The greater the amount of carbon the slower the combustion, until we reach the mineral known as graphite. This is nearly pure carbon and will not burn at all, so we make lead pencils of it, or use it as a lubricant.

Under modern conditions the production of coal as fuel is not the only concern of the miner. In former days much of the coal obtained was waste. Only blocks of a certain size were saleable or usable, and tons of slack went to swell the spoil heaps. This was an extravagant state of things and one which could not be allowed to continue. Nowadays the slack and inferior kinds of coal such as cannel are utilized for making oil and motor spirit. From 1 ton of ordinary Newcastle coal the gasworks extract 10,000 cubic feet of gas, 140 pounds of tar, and 25 gallons of watery liquid, leaving 1500 pounds of coke. The watery liquid used to be thrown away and the tar used for obvious purposes, but lately the value of both products has enormously increased. Oils, paraffin wax, ammonia, acids and alkalis of many kinds, creosote, naphtha, dyes of forty different colours, flavourings, scents, drugs—why, there is no end to the by-products of a ton of coal. Your grandmothers will tell you that grocers' shops to-day are full of things that were unknown in their young days, or so very dear as to be beyond the reach of all but the wealthy classes. This increase of the luxuries and refinements of life is due very largely to the "waste" from the gasworks and the brains of the chemists who have found a use for it.

To most people, however, the most wonderful part

of the story of coal is that which deals with mines and miners. We talk glibly and with admiration of the aviators who were the first to trust themselves to air—the new and untried element—but we rarely think of the first miners, those who ventured down into the bowels of the earth, a place of darkness and unknown terrors. Most of us, I am afraid, are cruelly callous about the world's most important people. Thousands of men go daily into the valley of the shadow of death simply to provide the rest of the world with comforts or superfluities. Coal we regard as a necessity, but is it one? Could we not, if we chose, exist without it? Undoubtedly we could, but the whole scheme of modern life would be turned topsy-turvy—a catastrophe one cannot face lightly. No, we must have coal, but we must try to remember the miner. He follows a dangerous and awful trade, and he deserves the greatest consideration from us all.

Sinking a mine is an expensive business, and one which may prove ruinous or profitable. In the first place, a stretch of country believed to be rich in coal is bored at different points. The boring tools bring up samples of rocks, and enable the engineer to construct a diagram of the strata underlying the surface. Seams of coal rarely run in straight horizontal lines. They rise and fall and wind about in rather a perplexing manner, and the lowest point has to be found. The first shaft is always driven to the lowest point for two reasons. The water always present in mines will drain, of course, towards this lowest point, so that is where the pumping machinery is erected. Moreover, a mine is easiest to work when the gal-



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SECTION OF A COAL-MINE

1. Winding-engine house, showing engineer controlling cage-raising machinery. 2. Shaft head.
3. Fan house. 4. Downcast shaft. 5. Upcast shaft. 6. Draft to fan. 7. Line of fault.
8. Goaf or worked seam filled in. 9, 10, and 11. Main roads. 12. Sump. 13. Pump house.
Arrows show the direction of ventilating current.

leries slope downwards. There is little labour involved in hauling empty trucks uphill, and the help of a downward grade to loaded trucks is obvious. Surface conditions also have to be studied. The mouth of the shaft must be situated near to a railway or waterway, to avoid the expense of carting, and it must be approximately in the centre of the coal, to reduce the length of the galleries as much as possible. When all these matters have been discussed and a course decided upon, the work of sinking the shaft begins. The first six or seven feet are dug out by hand, and then the sides are boarded up. As the shaft deepens mechanical tools have to be used. A derrick is erected to haul up the loads of earth, and hard rocks have to be cleared away by blasting. As soon as a firm bed of rock is reached the walls of the shaft are bricked. If the shaft is very wet the men line it as they go with cast-iron plates, called "tubbing", which hold up the walls as the boarding does, and also keep out the water. Another method of keeping back the water during shaft sinking is to convert it into ice. When at last the bottom is reached, two galleries are started, running in opposite directions. According to law there must be at least two shafts, and a second is sunk at a distance of not less than 15 yards from the old one, with which it must be connected by a passage at least 4 feet high and 4 feet wide.

By this time there will be all kinds of apparatus at the pit mouth. You will never guess what is being built at the bottom of the shaft. It is a stable. One day the cage will be loaded with little ponies that

are born and bred for no other purpose than to live their lives underground. Of course they have holidays, when they come up into the sunlight and enjoy the beautiful green meadows for a few days. But before the ponies come the mine must be ready for them. Galleries must be dug and timbered, and all the elaborate ventilating and pumping machinery must be installed. Nowadays the walls of the workings are often supported by steel props. These are twice as expensive to buy as wood, but they last six times as long. Bare Welsh mountains that would grow nothing else used often to be planted with larch trees. The people called these forests their banks, for they knew that in twenty-five years they could sell all their larch poles for pit timbering. I am afraid that with the advent of steel props many of these beautiful forests will disappear. The pit ponies also are being replaced by machinery, but no one can regret that any more than any humane person will deplore the day when coal-getting by hand is abolished.

The miner has many tangible dangers to face. Probably he never has the awful qualms which assail you and me when we venture ourselves in the cage and descend a mine. He has no terror of the sheer depth and darkness. He knows that every bit of the hauling tackle is examined every day, and that the danger of the rope breaking and the cage dropping with a thud is remote. But he knows—what you and I don't think about—that the ventilation of a mine is a purely artificial affair. Of the two shafts, one is called the *downcast* and one the *upcast*. We are descending by the downcast, and with us is going

fresh air. When we get out of the cage and walk along the gallery one of the first things we notice is a closed door. The miner who is conducting us opens the door to let us go through, but is most careful to shut it after us. The reason is that we are now in the gallery running between the two shafts. If the door were left open the fresh air would come from the downcast, rush through the gallery, and back to the surface again by the upcast. All the roads and workings of the mine would be left airless and impure, and the men at work there would suffocate, perhaps, before they could reach the downcast. The rules of all mines are most stringent as regards these doors, and with justice. One man's carelessness might result in death to hundreds. It is only by a system of doors and fans that a mine can be made habitable.

But a danger that is more apparent to us, who are happily ignorant of the risks of suffocation, comes from above. Suppose the roof should give way! And we seem to be walking so far from the shaft. Is it not rather foolhardy to venture so deep into the earth? Hadn't we better turn back? Our guide only laughs and tells us there are men now at work *three miles from the shaft*, while at Whitehaven a mine extends for *four miles under the sea*! I am sure our faces turn pale and that our hair rises just ever so little from our heads at the mere idea, but in the dim light of our Davy lamps we cannot see one another very well. The main roads are lighted by electricity, but now, as we want to watch the men at work, we have taken a side turning which is dark, low, and narrow.

Let us stop to watch a "holer" at work. A holer has an unenviable job. His duty is to cut away the bed of greystone, or "underclay", on which a seam of coal rests. The stone is only half a yard thick, but it takes some cutting. Afterwards it will be used to build props and pillars. As the holer cuts he supports the coal with wooden sprags. The space gets bigger and bigger, and the holer crawls farther and farther into the face of the rock. It is a ghastly sight to the inexperienced, but the holer does not seem to mind. At last he is finished, and crawls out with a grin on his black face. Not a moment too soon, we think, as we hear the coal groan and creak against the sprags. It is now the turn of three gentlemen known as "butties", who are, as it were, in charge of this particular lump of coal. The butties have to be very alert and nimble. I do not think I should like to be a buttie any more than a holer. It is his business to knock away the sprags which are holding up the coal—it is a little lump about 40 yards long and 3 yards wide—beginning at the ends and working towards the middle. The lump sways, staggers, and falls, but the butties have all skipped out of the way. It takes us quite a long time to recover from the noise and confusion, and by the time we look again the butties have disappeared, and two new workmen are on the scene. These are the "loaders", who break the coal into convenient-sized pieces and load them on to the wagons. Presently a boy and a pony come out of the blackness. A loaded wagon is hitched up, and the coal departs on its journey into the great world. If we follow it we shall see it hauled up to the surface

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A COLLIER HOLING

The holer has an unenviable job. It is his business to dig away the "underclay" on which a seam of coal rests, and to support the coal with wooden sprags. When he has finished, the sprags are knocked away, one by one, and the coal comes down with a roar.

and tipped from the trucks on to a screening machine. This contrivance sifts the coal and grades the lumps according to size. Large pieces of slate or stone which may have been loaded in with the coal are picked out by hand. It is, however, quite impossible to extract the worthless stuff from small coal simply by the eye, and a washing machine has been invented which distinguishes coal from rubbish with great accuracy. You will meet relations of this machine in succeeding chapters. A stream of water is the sifting instrument. The coal that is too small to be screened is put into a tank through which water is flowing. The stones, being heavier than coal, fall to the bottom, while the coal is carried away by the stream, to be collected at the end of the tank. It is now ready to be put on railway trucks and carried to market or to the wharf. Water carriage is the cheapest and most extensive means of coal transport, but it is not always possible. London's coal is nearly all sea-borne. If you read old books you will find references to a "fire of sea-coal", which simply means that the coal was brought by sea. Road carriage was impossible in those days, and before people began to pay attention to rivers and canals the depth of water in them was not sufficient to carry a heavily-laden barge.

Doubtless some of this coal which we have just seen excavated will go to the gas-works. Here the coal is put into retorts which are heated to a temperature of 2000° F. By the heat the gas is forced out of the coal, and leaves the retort by a series of pipes which connect with the hydraulic main. This is a receptacle above the retort where products other than

gas are deposited; that is to say, tar and the watery liquid. Sufficient tar is always left in the main to wash the gas as it passes through, the surplus falling into the tar well. The gas then enters the cooling pipes which encircle the retort-house. From these it passes into the condenser. There are many different kinds of condensers, but they are all made on the same principle, which is that by changing the direction of the flow of the gas its speed will be checked and any solid particles will be deposited. Thus some condensers are a series of vertical pipes up and down which the gas must travel; others are made in a horizontal-spiral and others in a zigzag pattern. Now the gas is treated by different machines, called respectively the washer, the exhauster, the scrubber, and the purifier, after which it is in a fit state to be received into the gasometers we have seen so often.

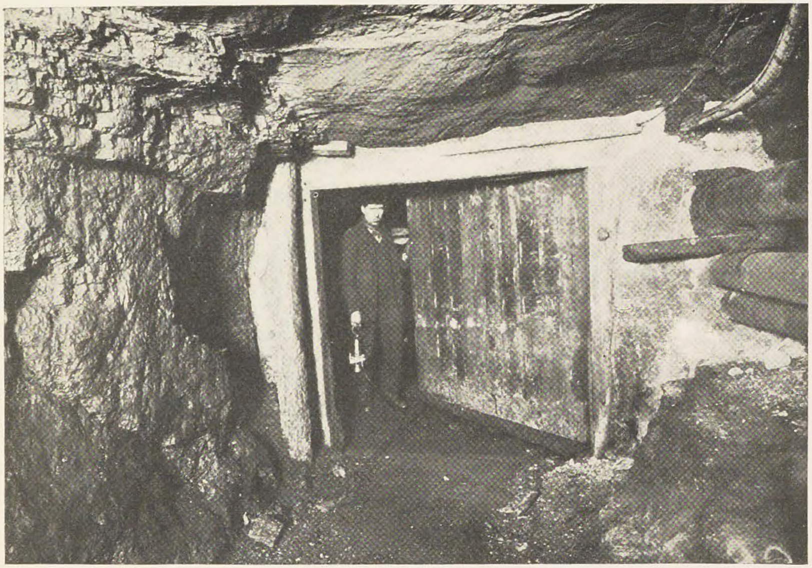
I am afraid that we have forgotten all about our guide who is waiting for us in the coal-mine. The holer and the butties are quite a long way off by now, compassing the fall of a new lump of coal. We cannot help feeling some surprise that they are still alive; but they have had so much practice in this particular kind of work that the danger is not really so great as it appears. The unexpected falls are the dangerous ones. Fifty-seven per cent of the fatal accidents in mines are due to falls of the roof or sides, but we hear little about these accidents, because, as a rule, only one or two men are killed at a time. The newspapers can make good headlines out of a fire or an explosion involving many lives, but "one man killed" is too common an occurrence to be worth reporting, for all

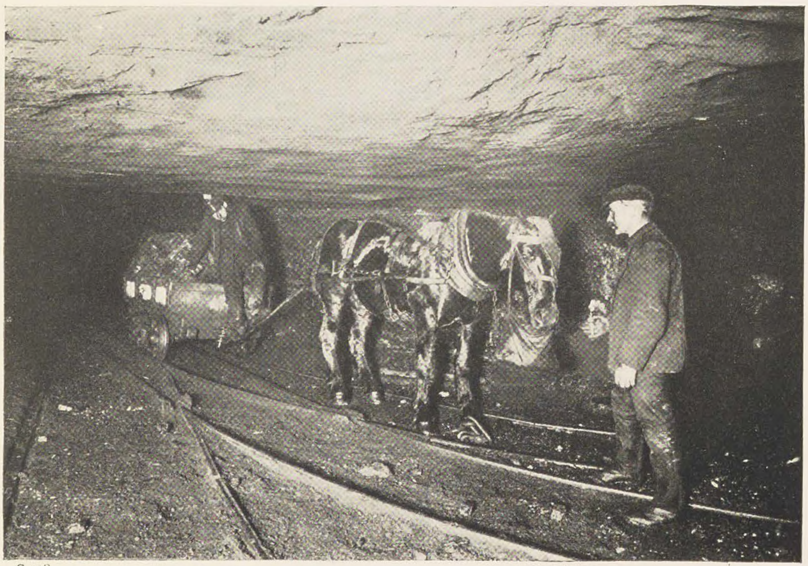
that he was somebody's breadwinner, somebody's dear son, or husband, or father. A great number of deaths are caused by accidents in the shaft, in spite of the precautions enforced by law and the daily examination of the gear. About a tenth of the fatalities are due directly to fire or explosions; but we must remember that a large proportion of the falls of stone are caused by explosions. More cases of deaths from falls are, therefore, due to explosion than to imperfect propping of the roof and sides or to the extraordinary "creeping" by which nature tries to fill up the cavities made by man.

The most deadly and insidious of the miners' enemies is the gas. There is always gas in mines; in fact, there are four different gases to be combated. These are carbonic acid (black-damp), carbon monoxide (white-damp), carburetted hydrogen (fire-damp or marsh-damp), and after-damp, which is a generic name for all the foul airs that creep through a mine after an explosion. I have told you that it is difficult to keep the air pure in mines. The men and ponies are absorbing the oxygen all the time, and they would soon be killed by the poisonous gases if fresh air were not constantly circulating through the galleries. But there is still one more complication to be considered, and that is the presence of dust. You cannot hack and chip at lumps of coal or stone without producing dust. In a dry mine this dust is a source of danger, because it is inflammable. An iron pick will strike fire from any hard stone, as you know, and one spark might be sufficient to ignite the dust. In an instant there is a sheet of flame, and if any fire-damp is about

there will be an explosion. To mitigate the dangers from dust it is now general to water the main roads of mines. A disastrous explosion occurred at the Pretoria pit, near Bolton, in February, 1911. Three hundred and forty-four lives were lost, and in the opinion of two very learned men, Sir Henry Hall and Professor Cadman, the catastrophe was caused by some particles of this very fine dust penetrating the gauze of a safety-lamp. The dust caught fire, and instantly lighted the highly inflammable gas present in that pit in large quantities.

The first coal-mines were more of the nature of quarries. The coal was obtained from seams on the surface, or so close to it that there was no lack of fresh air. As these seams became exhausted, however, men penetrated farther and farther into the earth's crust. It was not long before they found themselves confronted with unexpected difficulties. The first of these was water. The miners followed the coal-seams, which, as I said before, present a varied contour: thus in the low levels puddles formed which grew to ponds, and seriously interfered with the getting of the coal. The miners tried to reduce the water by a chain of buckets driven by a water-wheel or by a windlass turned by horses; but these primitive methods were insufficient. However, in this case, as in every other, the man was ready for the hour. In 1705 a Dartmouth blacksmith produced a pump worked by a steam-engine which, in the course of ten years, completely overcame the flooded mines. His name was Thomas Newcomen, and his pump was nicknamed the "Miners' Friend".





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VIEWS IN A COAL-MINE

At the top is shown a door for controlling the ventilation; the lower picture shows a pit pony hauling trucks.

So the colliers pushed on with their work and sunk mines deeper and deeper, until they met with another and much graver difficulty.

This was the gas. Little as men knew about ventilation in the early eighteenth century, they did know that air was necessary to life. They did not introduce enough into the mines, however, to have any effect in diluting the gas which accumulated in large quantities. An explosion was the inevitable result, and men had to turn their attention to the conquest of this new obstacle. The first means employed was crude in the extreme. When a gallery became so full of gas that it was dangerous to go into it, a "fireman", wrapped in blankets soaked with water, would go to the entrance of the gallery with a lighted candle on the end of a long pole. He would poke his candle into the gas-laden passage and then fling himself on to the ground. As a rule, the flames passed over him harmlessly. This was a hopeless method, as it only remedied the trouble for a time and did not strike at the cause. Carlisle Spedding was responsible for the idea of piping an escape of gas and carrying it to the surface. He also invented the first safety-lamp, an arangement of flint and steel which gave a dim light by a succession of sparks. Great improvements in the ventilation of mines were introduced by his son James. Yet mines were still in their infancy, and in the day of the Speddings no very great depths had been attempted. It soon became evident, however, that gas was not the only enemy to fresh air. If you were to start digging a hole in your garden you would, after you had gone down 20 feet or so, begin

to feel chilly. By the time you had dug another 30 feet it would make no difference to you whether the surface was hot or cold. Your atmosphere would remain at a fixed temperature. But if you dug another 60 feet downwards, you would find that it was getting warmer, for below a depth of 50 feet the thermometer rises 1 degree for every 60 feet. For the purpose of creating a strong draught great fires were lighted at the bottom of the upcast, but these often served to light the gases. John Buddle, of the Walls-end Colliery, improved matters by introducing two streams of fresh air instead of one; but he did far more for the miner by asking the advice of Sir Humphry Davy. Sir Humphry listened to his tale of troubles and catastrophes, and is said to have remarked: "Well, I think I can do something for you." What it was he could and did do the grateful Mr. Buddle knew seven weeks later. The Davy lamp is constructed on the principle that an explosion will not pass through fine wire-gauze. The flame is enclosed in a gauze cage, and if the lamp is held in a gassy atmosphere the flame, by becoming larger, warns the miners of the danger. The Davy lamp, unfortunately, is not invulnerable, for when the flame increases it heats the gauze, which is then liable to break.

A better lamp in some respects than Sir Humphry Davy's is that invented by George Stephenson, known as a "Geordie". Stephenson and Davy were working for the same end at the same time without knowing it. Davy was experimenting at the request of colliery owners in the safety of his laboratory:

Stephenson actually tested his experiments in the mine, and was driven to make his attempts by his own knowledge of the loss of life and limb among the miners. The flame of his lamp is surrounded by a glass chimney, while the cap and the air-holes are protected by very small tubes placed near together, between which he found the flame would not pass. In the presence of gas the lamp goes out, and so is much safer than Davy's.

The recent invention of a fire-damp detector, by Mr. Ralph of Newcastle, should prove of far-reaching effect in preserving the lives of our miners. This device is attached to an electric accumulator lamp and depends on the peculiar property of platinum, which has its electrical resistance increased by the presence of fire-damp. Fire-damp is not dangerous unless it is present in the air in quantities equal to about 4 per cent, but the instrument will register as little as a quarter per cent. Nowadays mines are largely lighted by electricity, and all sorts of precautions are taken to ensure that miners shall not open their lamps while at work. Terrible accidents still occur, but so much is now being done to improve the lot of the pitmen that we cannot but hope that wholesale slaughter such as occurred at Sengenydd in 1913 will never be repeated. Of course, ambulance and first-aid work has found a place in collieries for many years past, but a new development is the establishment of mine rescue stations. The first of these was opened on the 8th April, 1911, at Newcastle-on-Tyne. The station has a resident staff of eight men, trained to the use of rescue apparatus and motor vehicles. The

main equipment includes a motor-pump, a fire-tender, also motor-driven, and a caravan to provide living accommodation for the men when away from home. The pump can travel 37 miles an hour, and so can reach the farthest colliery in either Northumberland or Durham in an hour, and pumps 500 gallons a minute, carrying 1600 feet of hose. The tender is designed for use on occasion of explosions or underground fires. Constantly kept on it are five liquid-air suits of rescue apparatus, 2 miles of telephone wire, a small aluminium pump to deal with moderate-sized fires, and a patent box for carrying the canaries which are used for testing the air after an explosion. Colliery owners for the most part are only too anxious to adopt any measures which make for the safety of their men. A Bill recently passed by Parliament demanded that, in addition to the downcast for the conduct of fresh air, and the upcast through which the bad air returns to the surface, there should be a third shaft, to be used solely as an exit. About the same time a station for the testing of explosives to be used in mines was opened at Rotherham. As far as possible the actual atmospheric conditions of a mine are reproduced and the explosive is then fired from a gun. The effect is watched from an observation room running parallel with the testing chamber, through slots in the wall protected by thick glass and iron shields. So you see men are doing all in their power to render safe the always dangerous conditions under which coal-mines are worked.

It sometimes happens that miners are attacked by panic. I think it is not surprising that they are.

They are underground for eight hours at a time—eight hours of the hardest work, with only a break of twenty minutes for "snaptime" as they call it. Suppose you were a miner and that all your friends and relations were miners. Not a week would go by without your hearing of an accident, possibly fatal, to someone. And then you would go down to your work again and tramp through the galleries for one, two, or perhaps three miles before you reached your stall. Three miles from the shaft! Three miles from your only link with the surface! And while you worked you would think of poor Bill, or Joe, or whoever it was, struck down in his youth. And you would hear the gas, a long way off at first, hissing gently. As you listened to that hiss growing louder and nearer it would seem to threaten you. It would seem like some hideous evil coming closer and closer. What wonder if you "downed tools" and ran? And when one ran, others would run; and a knot of you would go clattering to the shaft, to creep back shamefacedly to your work when your nerves had quieted down.

Contrast this imaginary picture with the actual occurrences at Sengenydd. This story is told in the words of Mr. Clement Edwards, M.P.:

"Early this morning, about two o'clock, I descended the pit with Colonel Pearson, some mining engineers, and others, and went through the main intake, or road, up to the part at which men were playing on the fire. Both in the mainway and also in the cross-cut going off to the right what we saw was heart-breaking beyond words.

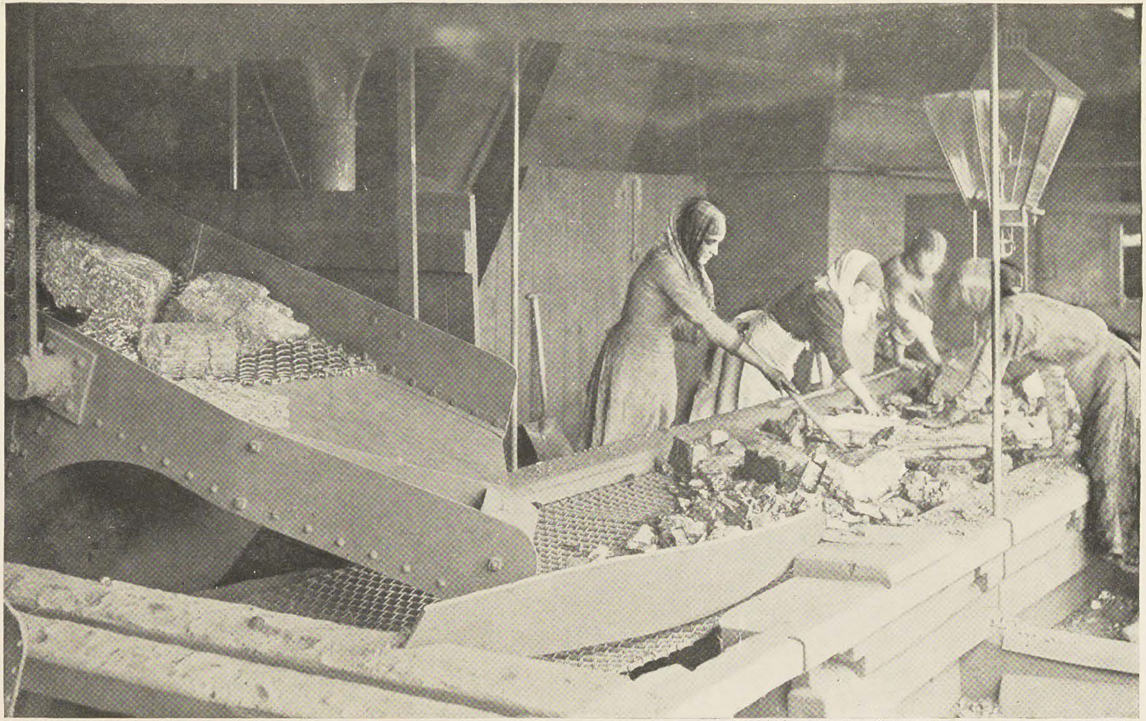
"Here the men have been continuously battling

with the flames under a great fall for three days. It looked as though their work would have to be abandoned. We crawled along the cross-cut on our hands and knees over smouldering debris. The heat was terribly oppressive. The roof was crumbling and falling. Yet a few yards from where poor William Johns, a member of a rescue party, was killed by a fall of roof yesterday we found men working earnestly, though they could only stand it for a few minutes at a time.

"It is a wonderful story, that death of Johns, which the world ought to know as evidence of the unspeakable heroism of the men who are working here. Within five minutes of the fall, more than a ton in weight, Johns's body was recovered. Ten minutes later the body had been passed back on the road, and with that single exception every man of that party was back in his place as though no fall had occurred to imperil all their lives.

"But to go back to this morning's work. Personally, I can stand a fairly high temperature, but I am quite sure that even without exertion of any kind I could not have remained for more than half an hour where these men were playing with the extinguishers on the fire. In order to do this properly they had to stoop or lie over a smouldering neap of debris from which fumes were rising. The heat was so great as to burn my clothes and boots.

"Not only were the men pouring water in front of them, but they were propping, with stout pieces of timber, the roof to prevent it falling on them. One could hear it cracking and creaking ominously.



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CLEANING COAL AT THE PIT MOUTH

The coal is shot on to a moving band, and as it passes the women they pick out the lumps of "dirt". It continues its journey to the screens, where it is automatically sorted according to size.

The danger of the position was magnified enormously by the situation in the mainway beyond the junction. With the cross-cut here the heat was oppressive, and the fall great. The smouldering floor was sending up noxious fumes, and above was a haze of gas of not less than 18 inches.

"We knew that if that innocent-looking haze came in contact with a sudden spurt or flash from the fire below, the explosion of last Tuesday would be repeated. Notwithstanding the imminent danger, the men, some twenty in number, continued to work with glorious pluck and persistence. What with the great heat and the hovering cloud of explosive gas in the mainway it looked, at three o'clock, almost as if it would be madness to allow the men to go on risking their lives for the gambling chance of getting out alive some of the poor fellows who are entombed in the distant working."

I could tell you a great deal more about coal and its wonderful story, but this book sets out to describe so many other things that I must occupy only a small space with each one. I will now go on to a most useful mineral which is a near relation of coal, and which provides us with the means of mining and machine-making.

CHAPTER III

Titans of To-day

You will remember, those among you who took a delight in the marvellous deeds of the heroes of Greek mythology, that the Titans were the offspring of Uranus, or heaven, and Gæa, the earth. They were giants of surpassing enormity; giants beside which the fellow that Jack slew would have seemed quite insignificant—and Jack's giant was a fair size. The Titans did no end of huge things, but none of them had, so far as I am aware, any connection with the subject of this chapter, which is iron and the form of iron called steel. Yet I think my chapter heading is a good one; for the adjective *titanic* expresses a colossal strength better than any other word in our language, and one needs the most powerful word to express fully the force and influence that iron and steel exercise in our world.

The orthodox way to begin a chapter on iron is to ask you what you would do without it—the iron, that is, for chapters are easily dispensed with. A silly question, since you can't give an answer and wouldn't if you could. You would not even be able to gain experience by practical abstention from the use of iron; you would die too quickly if there were no iron

in your blood or in the food you ate. Fortunately for him, man has never had to do without iron, beneficent Nature providing it in suitable forms for the use of his body long before he troubled his head about it. For iron is one of the most common substances in nature. I doubt whether you could pick up a handful of soil from any part of the earth's surface without finding iron in greater or less—generally less—proportion. We know, too, that it is one of the constituents of the heavenly bodies. Meteorites that have come to earth nearly always show a composition closely analagous to the iron ores used for smelting; sometimes these meteorites are very rich in metallic iron, some famous ones containing as much as 95 per cent of metal. Next November, when you set out to look for the annual display of celestial fireworks that takes place on or about the 13th of the month, remember that the earth's atmosphere is teeming with tiny bodies that, though they are then making their first acquaintance with our world, are yet composed of earthy matter. It will help you, just as the revelations of spectrum analysis will help you, better to realize the unity—the *oneness*—pervading the Universal Scheme.

Most of my readers will know how astronomers explain the meteoric showers, and their close connection with comets. This, indeed, is not the time for speaking of them. But I would like to tell you that it has been estimated that, on an average, in the course of a single day some seven and a half million meteors, large enough to be seen by the naked eye, come into contact with our atmosphere, to say nothing

of about four hundred millions of others, which can be seen through the telescope. Most of these are so small that the intense heat caused by their collision with the earth's gaseous envelope causes them to flash at once into incandescent gas. Some of them, however, are large enough to retain their density and fall to earth as solid lumps of matter. They may weigh, perhaps, a ton or more. One such lump fell in India in the seventeenth century, and from this "iron lightning" an emperor had forged a sword, a knife, and a dagger. There is in the British Museum a meteorite which weighs 3 tons, and much bigger lumps have been noted. Fortunately for mankind large meteorites are extremely rare. It is estimated that about a ton of meteoric dust is added to the earth every day; and one might be pardoned for thinking that in course of time our iron supplies must be considerably augmented from this source. Perhaps they are; a simple calculation will show you that in 3000 years 1,000,000 tons of dust would have been deposited. A million tons of meteoric dust sounds a great deal, but if it were spread over the whole globe it would be less than half an inch in depth.

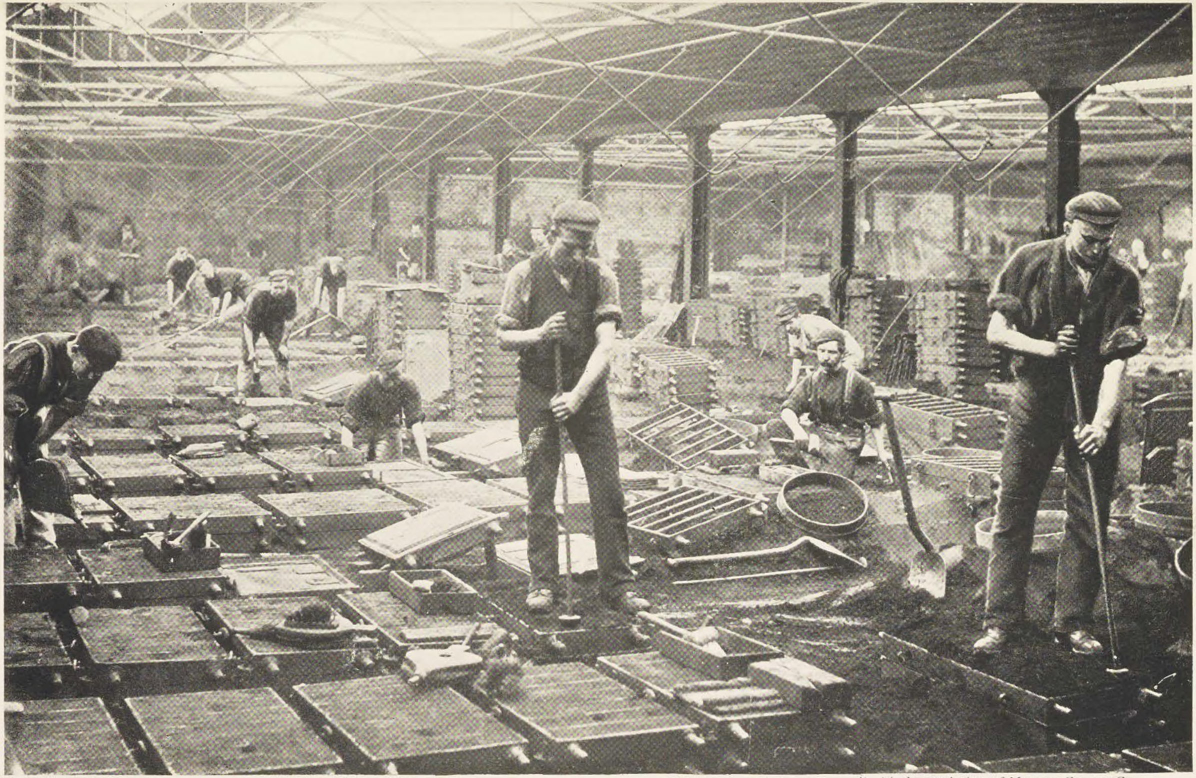
A million tons of iron-containing dust! Why, it is a mere nothing, a handful at most, compared with the quantity of iron ore that is tipped into British furnaces in the course of a single year. Do you ever pause to think how you and I and all our fellow men literally hunger for iron? Our appetites are insatiable; we can't get it fast enough. In this our Steel Age we want it for everything: for our houses, for our bedsteads, our thousand implements and

utensils of everyday use; our trains and trams and motor-cars and ships; our machinery in each and all of our industries. Britain now uses something like 25,000,000 tons a year in her own furnaces; and Britain produces less than a sixth of the world's pig-iron. Fortunate, indeed, that iron is plentiful! Yet the rate at which we are using it is a matter of serious concern to many investigators, for we are within measurable distance of an iron famine. Already we have used up some of the richest ironstone deposits in the world, and iron-masters have had to turn their attention to ores which are less rich in metal. Our titans are being fed to-day with food that they would have thought beneath contempt a little while ago. In other words, ore containing only about 25 per cent of metal is now smelted, whereas thirty years ago the iron-masters would have turned up their noses at ore that contained less than 50 per cent or 60 per cent of iron. This is not altogether a bad thing, for it has stimulated metallurgists to greater inventive activity, with the result that they are always discovering cheaper and more productive methods of dealing with the poorer ores that are coming into use. The main trouble is not so much the exhaustion of the iron supplies as of the coal supplies. In order to smelt 25,000,000 tons of iron ore, about 20,500,000 tons of coal are needed; and the coal is a far less plentiful treasure than the iron. In our day the commonest metal is the most precious, and one can scarcely conceive a greater world catastrophe than the closing down of the iron furnaces before we have ready another material, proved and found better,

to take the place of the one on which we are so dependent. Have I alarmed you? Well, rest assured that the dreaded day—though we know it must come—will not be yet awhile; nor will it come suddenly. We have ample warning, fortunately, in the international commissions that from time to time have been appointed to safeguard the world's iron resources. These bodies, composed of experts representing the iron and steel interests of the world, will see to it that our iron reserves are not recklessly depleted.

I am sure none of my readers need to be told that one of the greatest and most hopeful developments of industrial science has been the utilization of waste products. We are always coming across this phrase—the utilization of waste products—in our technical journals and our newspapers. And we should naturally expect that some sort of use was to be made of old iron, even if we had never come into personal contact with the picturesquely grimy dealers in that unbeautiful commodity. I am afraid the old-iron trade must be counted among those that are decadent, for nowadays the dust-bins of big towns are ruthlessly carted to refuse-destructors and assist in generating electricity for the town. Of course, the old iron is not burnt in these destructors, but is put aside and sold for re-smelting. A moment's reflection will show you what vast quantities of cast-off iron and steel there must be in the world; not merely old tins and pots and pans, but old machinery—a thousand things once big and formidably useful and costly.

And with the growth in the use of "enamelled"



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THE MOULDING FLOOR IN AN IRONWORKS

It is here that light castings are made. The floor of every foundry is composed of loamy sand in which deep pits may be sunk to bury large moulds. The caster makes first an exact pattern in wood of the article he requires, and this is pressed firmly down into the sand to make a shape. After finely powdered charcoal has been sifted over the surface all is ready for the liquid metal to be poured into the mould.

iron and steel ware, there have gone into dust-bins and rubbish heaps (forgive me for harping on refuse) thousands of tons of good metal, broken and battered and worn out, but still good metal, in that it can be used again to make steel. It has been estimated that London alone "produces" about 8000 tons of old enamelled ware a year, but until quite recently no one knew what to do with it, and it was just thrown away. All sorts of experiments were tried with the object of getting rid of the enamel, which is an earthenware glaze, and prevents the scrap from being used in a steel-converter. At last an ingenious inventor of Leeds introduced a machine which scrapes the enamel from the steel. The old enamel ware is fed into the hopper of this machine and then passes through several rollers, one of which is studded and recessed, another fluted, another corrugated, and the last one straight. The purpose of these rollers is to flatten out each piece as it leaves the machine. Now another machine takes the pieces in hand and strips from them every particle of enamel. By this process 1 ton of enamelled ware yields 17 hundred-weight of light steel scrap, and the machine can deal with about 40 tons a week. The steel makers are very glad to get the stripped metal, and what was once a complete drug in the market is now selling for about £2 a ton. Even the enamel is not wasted, but is sold to glass-works, metal-polish makers, and glazed-tile works. I have told you this to explain an industrial axiom which a great many people fail to realize—that what we throw away as useless to-day will be profitably utilized to-morrow.

The story of the development of the iron industries is a romance of the most enthralling interest. I wish indeed that it were possible for me to write about some of the great men who helped to make the Steel Age; the great things they did—how they forged the lever that moves the world, these fathers of the titans, and of the rebuffs and persecutions they suffered, as all great men and women are bound to suffer, because the world is littler than they. But there is so much in the earth besides iron that we have only time to take a cursory glance at the history of the grey metal and the work of those who have made it so useful to us.

The original discovery of the usefulness of iron was doubtless accidental. We should all be very much surprised if we could know how many of the fundamental processes of the arts and manufactures were due, not to invention or deliberate effort, but to purely fortuitous circumstances. It is almost as though Nature, kindly tutor that she is, gave man a helping hand from time to time during the course of his long pupilage; as though she said, "Why don't you try this way, you duffer? See how easy it is!" Lots and lots of discoveries for which credit is given to men were nothing more than broad hints from Nature. Obviously there could not possibly be any sort of metal work in the world until primitive man had learnt to make a fire, or so it would seem at a casual enquiry. And yet, why not? *Man has always had fire.* There has never been a time when the earth was not actually on fire in one quarter or another. The lightning stroke that set fire to

primeval forests, the blazing lava that flowed from volcanoes, the chemical reactions that cause carboniferous earth to be set alight by spontaneous combustion—it was from these sources that man first lighted a torch, long, long periods before he learnt how to *produce* fire, to kindle it for himself. In our own dear old county of Dorset, in this twentieth century of ours, there is a bed of coaly shale, known as Kimmeridge clay, that has several times caught fire spontaneously and poisoned the countryside with evil-smelling vapours. Still more to the point is the fact that there are well-authenticated instances of forest fires that have arisen from friction of the limbs or trunks of trees. The conditions necessary to the natural kindling of a fire of this kind are simple enough—a dry state of the atmosphere, dry wood, perhaps two dead and well-dried branches rubbing, rubbing together continually, as you can hear branches rub every time you go into a wood. Why should not primitive man, whose first fire-producing instrument was a fire-stick on this principle, literally have copied a process to which Nature so clearly pointed? Lying beside the remains of the earliest cave-men known to us were found flints cracked by fire, and bits of charcoal. Indeed, one cannot trace the time when fire was first kindled by man, so far, far away is it. "In what precise manner," says Lord Avebury, "Nature communicated this secret to our species is now difficult to determine. Even the few lowly tribes of our day that were devoid of fire-making apparatus had found at least some way of keeping the smouldering spark alive."

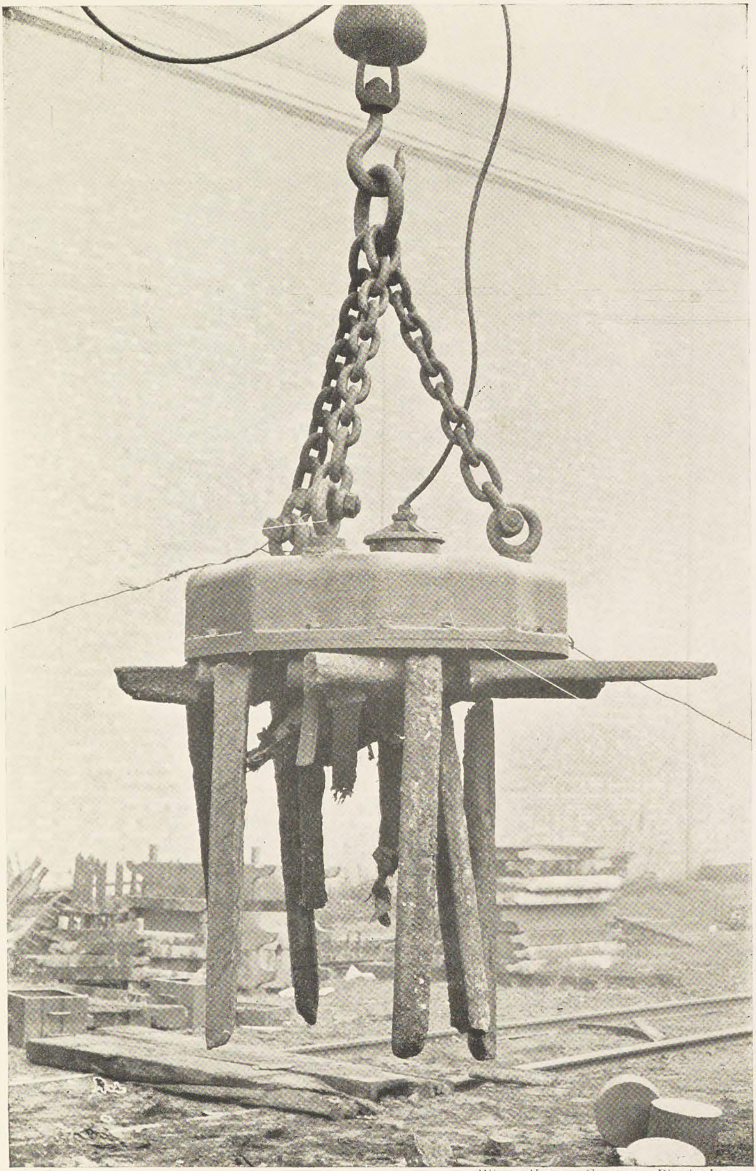
Doubtless it is a long step from the first fire, whether it was created by man's own hands or provided by Nature, to the smelting of metals. I have said that it was accidental: probably a big fire was lighted on earth very rich in metal, so that it smelted, and, by its strange nature, attracted the attention of that very inquisitive animal, primitive man. It must have taken a very long time before he had discovered how the gold or silver or copper or iron might be made into useful weapons and utensils; how much easier was the fashioning and shaping of it into implements than the chipping of a flint or piece of rock; how much more serviceable it was for spears and arrows than flint or shell, or wood hardened in the fire. Iron, you know, was not the first, nor even one of the first, metals used by man in his metallurgical experiments. I have spoken thus about fire and fire-getting because it was fire alone that could open the door of the primitive races, not merely to the use of metals, but to many others of the earth's treasures. Fire holds the key of the treasure-house; and I wanted to help you to understand how man discovered the key, or rather, stumbled on it. It is not necessary, however, for you to believe, as some people seem to think you ought to believe, that the common acquaintance of man and fire and metals is of relatively late occurrence in man's career — but rather the reverse. I have told you that we have almost positive proof, in the remains found beside the cave-man of Neanderthal, that this distinguished gentleman had a fire at his disposal; and a high authority tells us also that "it is not true, probably,

that men had to pass altogether through the rude and the polished Stone Age before they learned that some stones burned in the fire, some were scarcely affected by it, and others were rendered soft and tractable thereby"; and that "a metallic age may co-exist with one of rude and polished stone combined".

There is a good deal of doubt as to how the ancients smelted their iron, and in what quarter of the earth the art first originated. On the methods of some races of early metal-workers archæologists have been able to throw a good deal of light. The Britons were highly skilled in the use of steel when the Romans visited these islands, and the Romans themselves have left many traces of their iron-smelting operations. The early iron-masters were able only to make use of the very rich ores, and even then they obtained a very small proportion of the metal contained in them. They built their furnace on a hilltop, where the winds of heaven provided a natural but very inefficient draught for them. In the Forest of Dean the Romans left huge cinder heaps, and these heaps were so rich in unsmelted metal that for more than two centuries they furnished the whole source of the iron smelted in about twenty furnaces. It may be that the first furnaces were not unlike the pattern still to be seen in use in some parts of Africa. This furnace is made of clay, about 4 feet high, with a conical base for charcoal, and a goblet-shaped top for the crushed ore. There are four holes or "tuyères" at the base, by means of which a strong current of air is supplied to the furnace. In front of one of these is a pit for

the accumulation of the beads of crude metal. The shaft is lighted at the bottom, air is forced through, the ore is melted, and after about forty hours particles of molten iron begin to ooze through and collect in the pit at the bottom. The Bongo furnace is a little more elaborate, and is thus described in *Origins of Inventions*, by Otis Smith: "It has three compartments, the middle one for the reception of ore and charcoal in alternate layers, the upper and lower ones for pure coal. The chambers are separated from each other by ring-like incrustations on the inner wall. The bellows of the Bongo are formed of two trumpet-shaped earthen vessels, covered on their outer end with leather, and opening into a third one. All the negro tribes of Africa use such a bellows, with immaterial variations. The valve is unknown, a very imperfect substitute being secured by piercing holes in the handle at the centre of the hide and using the hands to let the air in and confine it." A very ingenious form of blowing engine has been in use for smelting metals for many centuries in some parts of Europe. This is the "trompe" of the Catalan or Castilian furnace, and it depends for its action on the falling of water. The water falls down a pipe having holes, through which air is drawn, into a tank or chamber. The water flows out of the chamber through a hole in the bottom, and the air, being unable to escape, is compressed to a degree which can be regulated by increasing or diminishing the flow of water in the pipe.

I am not going to trouble you with a description of the different kinds of iron ores that are used in



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THE MARVELS OF THE ELECTRO-MAGNET

A 42-inch-diameter lifting magnet handling pig-iron.

modern furnaces. I have said already that the amount of metallic iron they contain varies very much indeed. Some sorts—the famous Swedish ores, for example—contain as much as 75 per cent of iron, while others, like the vast beds of north-east Yorkshire, sometimes contain as little as 20 per cent. It is the development of these latter beds that has led to the rise of the town of Middlesbrough. Eighty-five years ago there was no Middlesbrough, but a solitary house standing on a forbidding-looking marsh; now it has a population of 104,000, and is one of the greatest iron and steel centres in the world. The utilization of the poor ores of the Cleveland district was started in Middlesbrough by a Mr. Vaughan, whose memory is very properly kept green by his townsmen. On the other side of England, in Cumberland, there are large deposits of a form of ironstone much richer than those of Cleveland, and more valuable for steel-making; and the rise of the town of Barrow-in-Furness has been a repetition, on a small scale, of what happened at Middlesbrough.

The growth of the iron trade during the last half-century is so huge that it is very difficult indeed to grasp its significance. In 1865 the world produced perhaps 8,000,000 tons, and this was probably from about twelve to sixteen times as much as was produced at the beginning of last century. Twenty years later (in 1885) the world production had risen to a little less than 20,000,000 tons. Fifteen years later (1900) the production had again doubled (40,000,000 tons), and in 1910 the output of pig-iron had reached over 65,000,000 tons. In the beginning

of the iron fever that gripped the whole civilized world Britain was far and away ahead of all other countries in the matter of production. In 1885 the United Kingdom produced as much pig-iron as was made in Germany and the United States together; and fifty years ago our country's iron-masters sent abroad, as a surplus for which they could find no use at home, as much iron as was produced by all the rest of the world. Now, and for a good many years past, Britain has been obliged to take a back seat. The United States have shot ahead and occupy by a huge margin the pride of place that used to belong to us, and Germany too, has beaten us, so that we only come third in the list of the great iron-producing countries, and a very bad third at that. I shall not now worry you with further figures, but it is worth while to pause for a second while we consider how this state of affairs has been brought about.

You know that the requirements of a prosperous iron trade are plentiful supplies of iron ore of good quality, coal, and the limestone that is used as a flux; and cheap and expeditious means of assembling these raw materials and of distributing the finished product. Nature has endowed our islands with good iron and good coal, placing them so that (at least in many cases) they lie actually side by side; and the flux was never far to seek, while our geographical position and the number of useful harbours on our coasts are inheritances of yet greater value. It was perfectly natural that, when men found that iron could be smelted with coal better than with the charcoal they were wont to use, our great natural and

economic advantages should give us a huge start of other countries less favourably situated. The industrial development of Germany and the United States had not then begun, and we had things so much our own way up to the 'seventies that it seemed scarcely credible that the lead could ever pass into other hands. The turning-point may be said to have come when the world cried out "Give us *steel*!" British iron was not best suited for steel. That of her rivals was. Our iron was of rather inferior quality, while Germany and the United States had vast areas of iron and all the coal needed to smelt it, and this iron was made into the best steel. These countries worked under such great natural disadvantages in the matter of carriage that their iron-masters had to seek the best means of production and the best means of giving their customers exactly what they wanted. We jogged along in the old ways, while they invented newer and better ways of making steel and selling it; though you should remember that it was to an Englishman, Bessemer,[1] that the invention of the steel-converter is due, and that an Englishman, Sidney Thomas, invented the basic process of steel-making—a process this that has proved to be of greater use to Germany than to Great Britain. I am afraid the attitude of British steelmakers towards their foreign customers was rather of the "take it or leave it" kind; while they are certainly to blame for failing to keep abreast—I speak of the trade as a whole, not of firms—of their more fortunately situated com-

[1] Henry Kelly, an American, experimenting about the same time as Bessemer, claimed to have achieved an earlier success.

petitors. In the nature of things this country could never have kept her pride of place in face of the vaster resources of her rivals; but it is sad indeed to have to relate that we have eaten more "humble pie" than we need have done, because we have neglected the efficiency that other countries so sedulously cultivated. This efficiency applies not only to iron and steel works, and to the researches of our metallurgists, but also to our railways; for there is not the slightest doubt that our manufacturers are handicapped by high rates for carriage, and are at a disadvantage in this respect compared with their German and American competitors. This problem of railway charges is a very difficult and dangerous one that will have to be taken in hand very seriously and very early if our country's industries as a whole are to maintain their proud position. Hitherto the tendency has been to shelve the question of railway rates, or to patch up the trouble in a manner to suit the political ambitions of a moment. It is a sad commentary on our political indifference that, although this problem affects our very existence as a manufacturing nation, we are always reluctant to take the trouble of trying to grasp its intricacies, and much prefer to leave it alone.

Here is my chapter more than half-written, and nothing said about the work our titans do; so, if you please, we will take tickets for one or another of the districts favoured by the giants and watch them from close quarters. Here is Middlesbrough, of which we have spoken before: unlovely in its outward aspect, but very wonderful in the vast power it wields, very romantic in the hidden meaning of its short history.

All around Middlesbrough, and in the other iron regions — Staffordshire, South Yorkshire, Lanarkshire, and many another shire—the countryside presents the characteristic appearance of an iron district. It is dirty, untidy, squalid in the last degree; blotched with spoil banks, slag heaps and mountains of refuse, overrun with futile-looking lines that end abruptly as though they had lost their ways, or disappear in long foggy buildings whence issue clangorous noises and bursts of furtive flame; a country of rude contrasts in natural beauties and thoughtless hideousness —for the iron-bearing regions are usually very beautiful before the titans spoil them; a country bearing battalions of chimneys, outposts of the huge towerlike structures of the furnaces; a land intersected by slimy canals, dark, gloomy, and treacherous, meandering among gaunt factories and desolate rows of houses. The houses, I think, would strike you most of all, on your first visit to the iron towns, for they form, above all others, a feature of the scene that is cruel and forbidding. There are no words powerful enough to describe the filthiness and beastliness of the dens and hovels in which the ironworkers are sometimes forced to live. The housing of the workers who toil that the titans may toil to supply our needs is a blot on our civilization. Think of the iniquity of it—that those who labour to provide the first need of our age (for iron in all its forms is a prime need) should be often obliged to live in the most villainous hovels amid surroundings from which every trace of beauty has passed away!

The great towerlike blast-furnaces, that seem to be

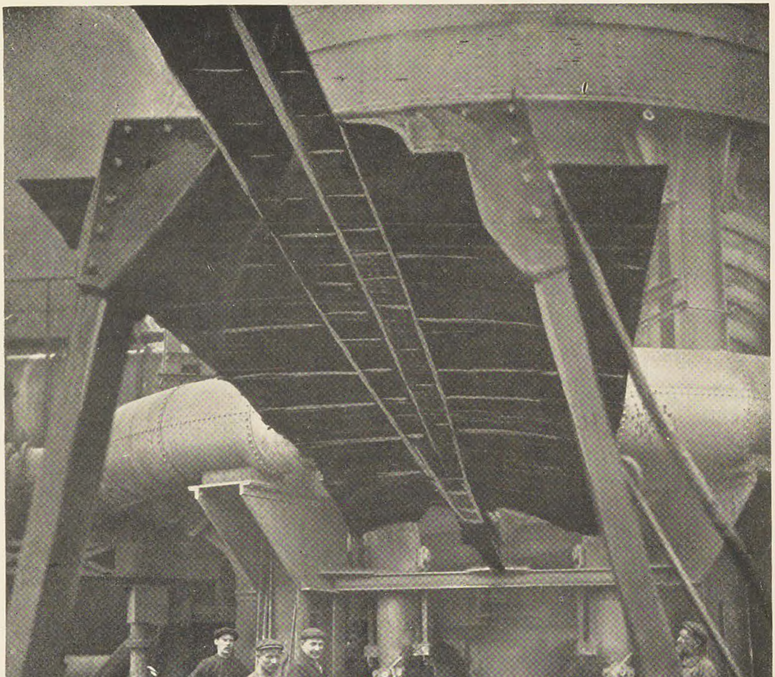
encumbered by so many excresences, in which the iron ore is smelted are worth a moment's attention. They are wonderful monuments to the ingenuity and power of man, as far removed from the primitive form of African furnace that I described a little way back as a cannibal's dug-out canoe is removed from an Atlantic leviathan. In this Cleveland district of Yorkshire, of which I am now speaking, the blast-furnaces as a rule are very large; I think it is a rule of the smelter that the poorer his ore the bigger his furnace, and the Cleveland ores are not very rich in metal. Imagine, then (if you have never seen a big blast-furnace), a black tower about 80 feet high and slightly tapering at the top; or, as this may mislead you, rather imagine several such towers clustered together in a group. Some of the towers are larger than the others, and have at the top a curious-looking gallery surmounted by a sort of scaffolding, all the towers being connected together by huge pipes. The large towers are the furnaces and the smaller ones the stoves for heating the blast. Further, you will notice that slender iron bridges run from one furnace to another; but let us go back to our single tower, dissociated from its fellows and shorn of its confusing excrescences, and see what it really is.

Our tower, then, is a hollow structure built up of masonry and strongly bound together by external bands of iron, so that, from the outside, one might think it was an iron tower. The interior of the tower is not straight, but is shaped so that it is wider near the middle than at the top or bottom—rather like two flower-pots put one on top of the other, edge to edge,

the top one of course being inverted. The widest part of the tower is nearer the bottom than the top and is called the "belly", while the top part—the upside-down flower-pot—is called the stack. The object of making the space greater at the "belly" than at either end is easily explained. It is highly important that when the materials to be smelted are tipped in at the top of the furnace, they should fall right down on to the mass below and not stick to the sides of the trunk. When, however, they have got rather more than half-way down, they are burning so fiercely that there is a great reduction in their bulk, and the furnace is shaped accordingly. The inside of the masonrywork of the tower is heavily lined with fire-brick, this "shirt", as it is called, being specially thick in the region where there is greatest heat. The "shirt" is not built in actual contact with the trunk, a space being left between them, which is filled up with some material which allows for the shrinking or expansion of the interior. Sometimes big furnaces have double linings or "shirts" with an insulating space between them. At the bottom of the furnace is the hearth, with the crucible for holding the molten metal as it flows down, and just above the hearth are the tuyères by which the blast enters the furnace. Tuyère, a French word meaning nozzle, is generally corrupted into "twyer" or "tweer", and you can use whichever form you please, though if you spoke of tuyères to a furnaceman, he would certainly wonder what on earth you were driving at. The tuyères are two pipes, one inside the other, with an annular space between them. The air is blown through the inner

pipe while a stream of water is kept circulating between it and the outer one, to prevent them melting.

The ore, fuel, and flux are cast in at the top of the furnace, and as it is important that as little heat as possible should be allowed to escape while the charging is carried on, a special form of "lid" or stopper has to be provided. The mouth of the tower—"the throat", in technical phrase—is shaped like an oilman's funnel that has had the "spout" knocked off, so that it has the form known as a truncated cone. The larger diameter of this truncated cone is fixed at the top of the tower, the end of lesser diameter pointing downwards. The stopper is shaped like an inverted pudding-dish, and is held tightly against the truncated cone by means of a chain and counterweights. The trucks containing the ingredients for the furnace are tipped into the funnel, and lie upon the inverted "cup" or pudding-basin that seals the opening to the furnace. As soon as the cup is lowered the charge of ore, fuel, and flux falls down its sides and so pitches headlong into the furnace. The blazing gases inside cannot escape while the stopper is open, because they beat against the inside of the cup and are turned downwards by it. Of course, the stopper is opened only for a few seconds at a time—just long enough for the charge to enter the furnace. How, you might very reasonably ask, from what I have just said, how do the gases find a way out of the furnace, since the top is kept so sedulously close, and there is no chimney? Chimney there is, of course, or the furnace could not burn. It is called a "downcomer", a monstrous pipe that leaves the furnace near the top



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A STREAM OF IRON

The illustration shows iron at white heat running through the mould in the ground.

and leads the gases into a great cylindrical erection called a stove. Even then their journey is not finished; from the stove they pass to the boiler furnaces, where the rest of their heat is utilized in helping to generate the steam that drives the blowing engines.

All modern furnaces use a hot blast for smelting the iron. The difference between the hot and cold blast is best expressed as an enormous saving of fuel by the former method. It was a long time before iron-masters could be brought to see the advantages of the hot blast. They had an idea that the colder the air they forced into their furnaces the better they burnt. It was left to a great investigator named Neilson to show them how utterly wrong they were. James Neilson was the son of an engine wright, earning about seventeen shillings a week, and his career is in some degree a parallel of that of George Stephenson. Indeed, than Neilson's there are few names more worthy to be remembered in the history of great inventions. After many bitter disappointments Neilson was allowed to experiment with his hot blast at an ironworks near Glasgow. This was in 1829 or 1830; and within a few years of its introduction his invention had been applied in every important iron-smelting centre in the world, and had been the means of directly creating a whole group of new ones.

The blast is provided by an engine, and is passed through the stove to which I referred just now. It is made to traverse a number of pipes surrounded by the incandescent gases brought from the furnace, and hence is raised to a great heat. From the stove it is led directly to the towers and rushes through

the furious mass inside the furnace with a fierce energy.

I have mentioned that at the top of each furnace there is a gallery, and that each group of furnaces is connected by bridges from one unit to another. As the furnaces are fed from the top it is obvious that there must be means for hoisting the ingredients to the place where they are to be pitched in. Sometimes the trucks are hoisted to the charging platform by perpendicular lifts, but there seems to be a tendency to employ elevators in the form of an inclined plane. The skips are attached to an endless chain moving on this inclined plane and are hauled to the top of the furnace and tipped into the funnel above the stopper entirely by mechanical agency.

Before the ore can go into the furnace it has to be dried in a kiln, and so also has the limestone that is used as a flux; though this process is sometimes dispensed with in dealing with poor ores such as are generally used in the largest blast-furnaces, the ore and flux being sufficiently dried during their passage through the long "stack" of the furnace. You know, of course, that the flux is added in order to free the metal of as much as possible of the earthy impurities with which it is associated. Under the action of the intense heat the lime combines with the silica in the ironstone and forms a molten slag or cinder —a scum —which floats on the top of the liquid iron and can be drawn off through a special opening. The iron is continually falling down into the crucible at the bottom of the furnace and is run out into depressions made in a huge bed of sand. There is a main channel

in the sand down which the molten stream flows, with several smaller branches leading from it. There may be ten or eleven such branches, and to each of these in turn there are from twenty to thirty yet smaller openings called pigs. When the iron has cooled in these channels in the sand it is the crude pig-iron of commerce. It is quickly moved out of the way, and the sand again prepared to receive a fresh flood of blazing metal from the furnace.

The blast-furnaces are always at work, night and day, weekdays and Sundays. It takes them such a long time to get hot that they are never allowed to go out, except at rare intervals for repairs. And there is something almost terrifying about the insatiable appetites of the monsters. Some of them will swallow up about 800 tons of ore, coal, and flux in *a day*—say 5000 tons in a week! Do these figures help you at all to realize the almost incredible strength of our titans, and how easy it is to talk and think of iron as a wave that is overwhelming the world—measurable only in millions of tons? Yet a furnace that is fed with 5000 tons in a week will not yield a third of its weight in pig-iron. There will be about an equal amount of slag; while the remainder—a good third of the whole, roughly speaking—disappears as the products of combustion. I had almost said "disappears in smoke", but that might mislead you. The missing third is certainly not wasted, since it is by its heat-energy that the iron is reduced from the ore, the blast heated, and other useful work performed.

The pig-iron that comes from the blast-furnace is the cheapest and coarsest kind of iron, and has to be

put through many processes before it can be made into manufactured articles. It contains many impurities that the fierce heat of the blast-furnace has not been able to remove. If the iron is wanted for castings the pigs are melted again in another furnace, from which the iron runs direct into the moulds in the casting floor of the foundry; but if wrought or malleable iron is wanted, then the pigs have to be puddled. This puddling of the iron is one of the most interesting processes in the whole glowing story of iron working. The puddling furnaces are quite unlike the blast-furnaces just described. They are built in rows or batteries and look something like bakers' ovens. Each furnace has two compartments, separated by a low division or bridge and an arched roof. The front compartment is for the fire, the hinder one being the bed for the iron. When the fire is blazing the flame surmounts the bridge and "reverberates" down upon the iron in the bed, and passes along a flue to the chimney. There is a door or "stopper-hole" in the front of the furnace, through which the puddler works his long "rabble". First of all the puddler "fettles" his furnace by plastering it all over with a paste made of very rich ore ground up in water; then the charge —about 4 hundredweight of crude pig-iron broken up into lumps—is put in. When the charge is melted the puddler takes his rabble, which is a long iron bar with the end turned up, something like a hoe; with this he stirs up the molten metal, working it backwards and forwards with great energy.

You may think that it is a very extraordinary thing that this process, which is so dreadfully exhausting

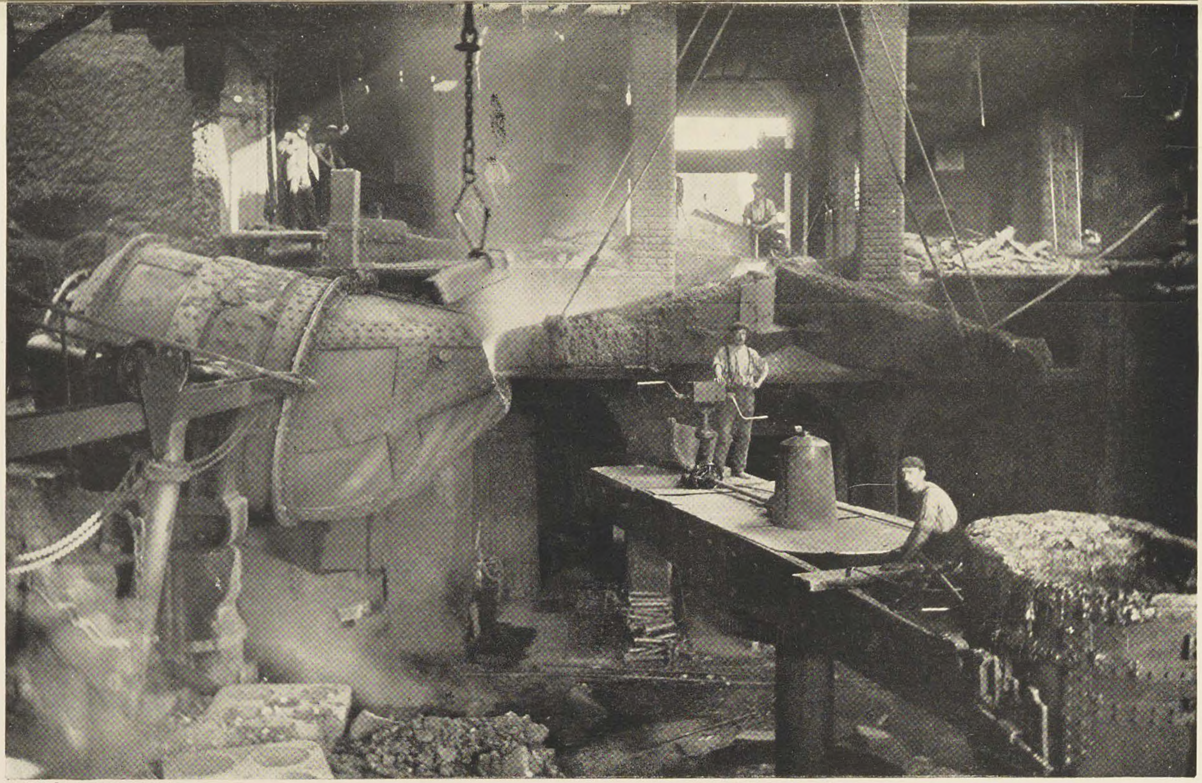
that I know nothing that equals it, is practically the only one that still has to be done by hand. Whether a mechanical puddler will ever take the place of the human is more than I can say, though it would be an easy prophecy to hint that it will; but up to the present no satisfactory invention has come to the relief of the poor fellows. Try to imagine how you would feel if a puddler put his rabble in your hands (it requires a young Hercules to lift it comfortably) and told you to work his furnace for a quarter of an hour. I am almost certain you couldn't do it. I doubt even if you could stand the heat of the furnace; for (unless you have been very close to one) you can't know what horridly hot things they are.

I was once called upon, in an emergency, to take a "trick" in the stokehold of a small steam yacht. It sounded very easy to keep steam in a small single-ended Scotch boiler, but I soon found that the furnace was much too greedy, the shovel much too big and heavy, the room far too little, and the coal uncommonly disobliging. Also it was annoyingly hot. I felt that I must either take off my clothes or die an awkward, ingnominious death; I must either undress or dwindle to a puddle, and in order to get rid of my clothes I had to lean hard against a bulkhead to avoid being pitched into the furnace every time the boat rolled. That undressing was really an awful experience, but worse was to come; unclad, I found myself a prey to new terrors and tortures, things hit me and bruised me terribly, coals made vicious rushes at my ankles, the fire seemed a thousand times hotter than before, and I was nearly roasted alive. With

one hand I clutched my torn and blackened garments, with the other a rung of the ladder that led to fresh air and safety. At that moment the engineer, coming down the "fiddle" to find out why there was no steam, put his foot on the rung I seized. It was a heavy foot, and my crushed knuckles still serve to remind me of the culminating misery of my stoking experience.

Well, though the iron puddler works his rabble in the seething, bubbling, spitting iron for short shifts only, I can promise you he is not a man but a sort of half-animated damp rag at the end of each shift. The end of the rabble itself softens, after a few minutes, and then he changes it for a new one. After he has laboured awhile the molten iron begins to congeal and his task is harder than ever. His business is to *wash* the iron in the molten slag, to free it of its impurities, and he does this with his rabble just as a washerwoman uses her knuckles (I believe) when she washes the clothes in soap and water. He collects the iron into two or three huge lumps, each weighing, say, 50 or 60 pounds, and then draws them, glowing hot, from out the furnace. A steam-hammer next takes charge of the balls, crushes them together and squeezes more slag out of them; after which the mass is taken to the rolls, when they are squeezed still further.

So much for iron, or rather, so little; for we have only glanced at the more stupendous feats the titan has to perform before his product is ready for our boilers, ships, houses, knives and forks, and motor-cars. And before this chapter comes to an end something must be said about steel.



C 708

CHARGING THE CONVERTER IN A STEELWORKS

The converter consists of a wrought-iron shell lined with a kind of sandstone called ganister. It can be turned out to receive the metal from the runners, and when sufficient metal has been run in, it is slowly brought to an upright position. Converters hold about 6 tons of liquid iron and some even more than this amount.

It is very difficult indeed to find a popular definition of steel, this metal that has ousted ordinary forms of wrought and cast iron for nearly all purposes where great strength and durability are required. I was going to call steel a carbonized form of iron, but I think this would be misleading, as some steels have less carbon than some kinds of iron, and some more carbon. The difference is a physical rather than a chemical one, and has to do with the structure of the metal. Those of you who read *Conquests of Engineering* may perhaps remember that in speaking of the Forth Bridge, I mentioned that it had been shown that if the Forth Bridge had been built, not of steel, but of wrought iron, the material of which the Menai tubular bridge is made, it would just be able to support its own weight and nothing more. A steel Forth Bridge is able to withstand huge air pressures and the strains set up by the passage of moving trains: a full-size replica of the Forth Bridge in iron could not withstand a breath of wind, or support even a few pounds' weight, without giving way. I think this is the best illustration I can find, at the moment, to show the main difference between the two materials. So let us say that steel is, weight for weight, a stronger, tougher, harder, and more durable substance than iron. But even this is far from being strictly correct. Steel can be made hard or soft; brittle as a razor-edge, pliant as in a rope—in fact there seems no end to the qualities that can be given to this truly amazing metal. A recent writer well summed up these qualities when he said: "Capable of being forged by hammering or rolling, or of being cast to almost any shape in a

mould, of being bent without losing its tenacity, of being cut and welded, of being drilled and riveted by the use of itself when properly composed and tempered for the purpose, steel has taken command of all other constructive materials, such as wood and stone, and has deposed them into quite a secondary place, so that they become little more than accessories to its pervasive strength and adaptability."

There are three principal methods of steel-making, and several minor ones that are used more especially when the product is required for particular purposes. Of all the processes the Bessemer is the most important. Pig-iron is melted in a furnace, and run therefrom into a huge vessel called a converter. The converter is pivoted, and is tipped downwards so that the iron can easily be fed into its mouth. When it has been charged with 10 or 15 tons of metal, the converter is swung back to a vertical position and a terrific blast of cold air is blown through the "twyers". It is a magnificent sight, though rather a terrible one. The air roars through the mass, raising it to a terrific heat, and burning out all the substances except the iron. A huge jet of flame quivers at the angry mouth of the converter—violet, orange, white, in turn—as one element after another is driven out; then the flame becomes a pale transparent olive and the iron is virtually pure. To convert it into steel a carefully-measured quantity of carbon is added, in the form of ferro-manganese, or *Spiegeleisen*; the blast is again turned on, again there is a violent seething and roaring, and then the steel is poured into moulds and allowed to cool into ingots. The product of the Bessemer con-

verter is known as mild steel, having a very low proportion of carbon. It is rather like wrought iron, but is inclined to be brittle, because, in spite of its drastic treatment in the converter, it still contains a good deal of phosphorus, a substance which it is very difficult to eliminate. Bessemer sought to avoid this brittleness due to phosphorus by using only pig-iron of high quality, such as that made from hæmatite, an ore containing little phosphorus. But then the steel-maker was debarred from using the cheapest and most plentiful ores. It was left to Messrs Thomas & Gilchrist to invent a process by which the phosphorus could be got rid of. They used lime in the converter to absorb it. Theirs is known as the "basic" process, and its introduction had two remarkable developments: the first was to bring Germany into the front rank of steel-producing countries, by making available her vast deposits of phosphoric ores; the other, the gift to agriculture of a very valuable manure, the basic slag or phosphate of lime that is the refuse from the blast-furnaces. There is yet another steel process, the Siemens-Martin. In this, high-grade pig-iron is melted in a crucible, to which scraps of old steel are gradually added—rails, shearings of plates, and so forth. Although such steel scraps are practically infusible in large bulk by ordinary methods, they melt readily when added bit by bit to a bath of molten iron. By the proper selection of the scrap a very high degree of purity is attainable, and the steel by the Siemens-Martin process is of fine quality. Samples are taken from time to time in ladles for testing, and when the correct quality is

attained the steel is run off into moulds as in the other processes. But enough is always left in the crucible or "bath" to continue the melting of the steel scrap.

The latest developments of steel-making are those which tend to make the metal more adaptable for special purposes, especially for cutting itself. Steel must cut steel, since we have nothing else to cut it with. You know, of course, that steel can be *tempered* to a great range of degrees of hardness. With the introduction of hard, tough steel for a hundred mechanical purposes came the need for something better than the simple tempering. A razor has a fine *temper*, but it only cuts hair; a carpenter's chisel, too, cuts but wood. What of the tool that is to slot machinery or drill tough armour plate? A great many parts of machinery that require to be specially hard are shaped and machined first, and afterwards hardened on their surfaces by a process called case-hardening. The highest class of steels are those you must have seen referred to often and often again, in advertisements and newspaper articles, as "high-speed" steels. These steels are really alloys of steel and some of the rare elements we shall discuss in a later chapter—chromium, tungsten, "vanadium", &c. A good deal of nickel-steel is also used. Some of these special steels cost hundreds of pounds a ton, and metallurgists are continually striving to outdo one another in inventing new and better compounds. I think you must go for yourself and visit a big machine shop and the wonders that will there be unfolded to your eyes, before you can realize the almost unthinkable strength of "high-speed" tools.

CHAPTER IV

Silver and some Common Metals

YOU may think it strange that I have classed a noble metal like silver with the "common" metals. As a matter of fact they are all more or less closely connected, and several are found together in the same mines. Silver and lead are two metals that are very closely related. Yet even if there were no immediate connection between them we might well class them together on account of their close resemblance. Where's the resemblance? Well, I grant you that an old lead pipe is not much like a beautifully-wrought silver ornament, but if you saw a lump of new lead gleaming with its own lustre, side by side with an ingot of rough unpolished silver, you would certainly agree that there was a similarity. The lead, alas! soon tarnishes and loses all its beauty, while silver advances to a life of ease and luxury. Both substances have their proper place in the world; both were known to the Romans, who made pipes and vessels of lead and mirrors of silver. The Romans made their pipes of sheet-lead, and apparently never discovered the process now in use. To-day lead pipes are made by heating the lead slightly and pressing it through a mould. It is a very soft metal. You can scratch it

easily with your thumb-nail and cut it with a good knife. It is very malleable and moderately ductile, but its tenacity is small. The purpose for which lead is chiefly used is for pipes and gutters to our houses, as it will stand a great deal of wind and weather and is not harmed by damp soil. Hot water soon injures it, and you must not think that it is impervious to the action of cold water. Rain or water containing bicarbonate or sulphate of lime dissolves lead very rapidly, and in this way a double evil is effected. The pipes are destroyed and the water, if you drink it constantly, will give you lead poisoning. Lead also is used largely for making shot, and for making large receptacles for holding sulphuric acid. Rolled out into sheets it becomes a useful roofing material. Several lead alloys are commercially valuable. Type-metal is an alloy of lead, tin, antimony, and copper, solder is lead and tin, and lead enters into the composition of pewter.

We do not find much of either lead or silver in a pure state; not half enough, in fact, to supply our needs. We can extract them both from an ore called galena, and lead alone is extracted from other ores, such as cerusite or native carbonate of lead. The mines at Leadville, in Colorado, produce this last-named ore in enormous quantities. The ore is broken up into small pieces and roasted in a furnace, after which (in the north of England but not in all lead districts) it is removed to an ore hearth called a "Scotch furnace" and smelted with the help of a blast of air. The smoke from lead-smelting furnaces is charged with lead. Not only would there be a great

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Photo. Underwood & Underwood.

THE SMALLEST SILVERSMITH IN HOLLAND

This busy worker of Schoonhoven has his dinner cooked upon the same stove as he employs for melting his silver. His weekly earnings amount to 10*s.*

deal of waste if this smoke were allowed to escape, but it would destroy all vegetation in the neighbourhood, and perhaps even poison animals. If you have ever been in a lead district you will know how this difficulty is overcome. You will have seen the ridge like a great drain pipe climbing over the moorland and the hillside, culminating at last in the great chimney which is a landmark for miles around. That is the flue from a lead-mine. Often these flues are several miles in length. The fumes condense as they pass through the flue, and the lead deposited is collected afterwards.

Galena is always *argentiferous* or rich in silver, and the method by which the silver is separated from the lead is a very interesting one. The average amount of silver in lead obtained from galena is about nine ounces to the ton, but it is a profitable process, even when so little exists as two ounces to the ton. By the process known as Pattinson's, the lead is melted in a cast-iron pot and then allowed to cool gradually while being stirred briskly. Now pure lead solidifies at a higher temperature than lead alloyed with silver, so you can guess what happens. The purer lead solidifies first, the argentiferous lead remaining molten. The two then are separated, and both are subjected to the same process again and again. When a proportion of 250 ounces of silver to the ton of lead is reached, the silver is obtained from the lead by melting the mixture in a reverberatory furnace. A reverberatory furnace is one in which the fire is not allowed to come into contact with the ore to be melted. There is a brick arch

between the fire and the ore hearth, and the heat is reflected or reverberated by this arch.

For centuries the world's silver storehouse was America. It is only with the development of Australia in modern times that the mines of New South Wales have become famous. In 1909 the output from Huanchaca, in Bolivia, was 5,591,000 ounces; while the Broken Hill mine, New South Wales, produced 7,727,877 ounces in 1890, and 1,718,005 ounces in 1909. But the silver mines of Germany have been really of more service to the world than those of any other country, not on account of the resources of the mines, but on account of the scientific research which they inspired.

The mines of Bohemia and Saxony, like others which we shall consider later, were discovered by accident. As long ago as 1170, a Bohemian labourer was wandering through a dense forest. He was a poor man, and having been unable to obtain work in his own town, he had set out to walk to the next. Being overcome with weariness he at last sat down to rest, and as he was pondering sadly he was struck by the appearance of a stone which lay at his feet. He had seen many others like it before in the Hartz, so he resolved to take it with him to the town and have it tested. It proved to be galena, heavily loaded with silver. Our friend promptly gave up the idea of looking for work, and with some fellow workmen he returned to the forest to look for silver. For some years they continued working by themselves, obtaining enough to live upon. At this time there were prosperous silver mines in the Hartz; but the Duke of

Brunswick, to whom they belonged, made himself unpopular, and the miners revolted and struck. In a body they marched to the forest and offered to work the mine there. Needless to say their offer was accepted, and they established a village which they called Christiansdorf, afterwards changing the name to Freiburg. The mines continued to be worked for centuries, and a school of mining was established, at which Werner became Professor of Mineralogy. Abraham Gottlieb Werner is a name you must remember, for he did much to develop and foster geological investigations. His classification of the rocks of the Hartz mountains is not now accepted as correct, but the controversy which he started led other scientists to expound and elaborate their views. Werner held the view that volcanoes were all of recent date, and denied the igneous origin of rocks. His chief adversary was James Hutton, who, with his disciples, John Playfair and Sir James Hall, maintained and demonstrated the importance of volcanic action in the formation of the world. Followers of Werner were called Neptunists, on account of his theory that all rocks were formed from water, and the followers of Hutton, Vulcanists.

Silver occurs in most European countries, but the most famous mines are at Kongsberg, in Norway. They have been worked since 1623, and have produced an enormous amount of metal, but are now nearly exhausted. The silver mines of Spain are mentioned by Strabo, who says that fully 40,000 men were employed at Carthagena. In the British Isles there are no true silver mines. Nevertheless our lead

mines produce not less than 200,000 ounces of silver annually. The richest mines are those in the Isle of Man, which yield 40 ounces of silver to the ton of lead, while a single mine at Alston Moor has been known to yield as many as 80 ounces to the ton.

Mexico at one time produced enormous quantities of silver, in fact more than a third of the silver of the world used to come from Mexico. The Mexican method of freeing the silver from the ores in which it is found is a primitive one, having been invented in the sixteenth century. It consists in making an amalgam of silver and mercury, and afterwards separating the two substances by distillation. This is known as the Mexican or Patio amalgamation process. In the first place the ore is broken up very finely. Then, in a circular trough having a hard stone bottom and a central shaft carrying four revolving arms, it is ground to a fine powder and mixed with water to form mud. The mud is partially dried and worked into flat circular heaps, which are then covered with a certain quantity of salt earth. The salt earth is well mixed with the ore, and the heaps are then flattened and made circular again; and horses walk over them for two hours. Next, roasted sulphide of copper (magistral) is mixed in, and the horses do another two-hours' trot. After this mercury is added in small quantities, the horses being brought into use after each operation. The process continues for about a fortnight or more, according to the season. It takes least time in the summer, when the heat assists the drying of the amalgam. When the amalgam is ready it is distilled in a cylindrical retort.

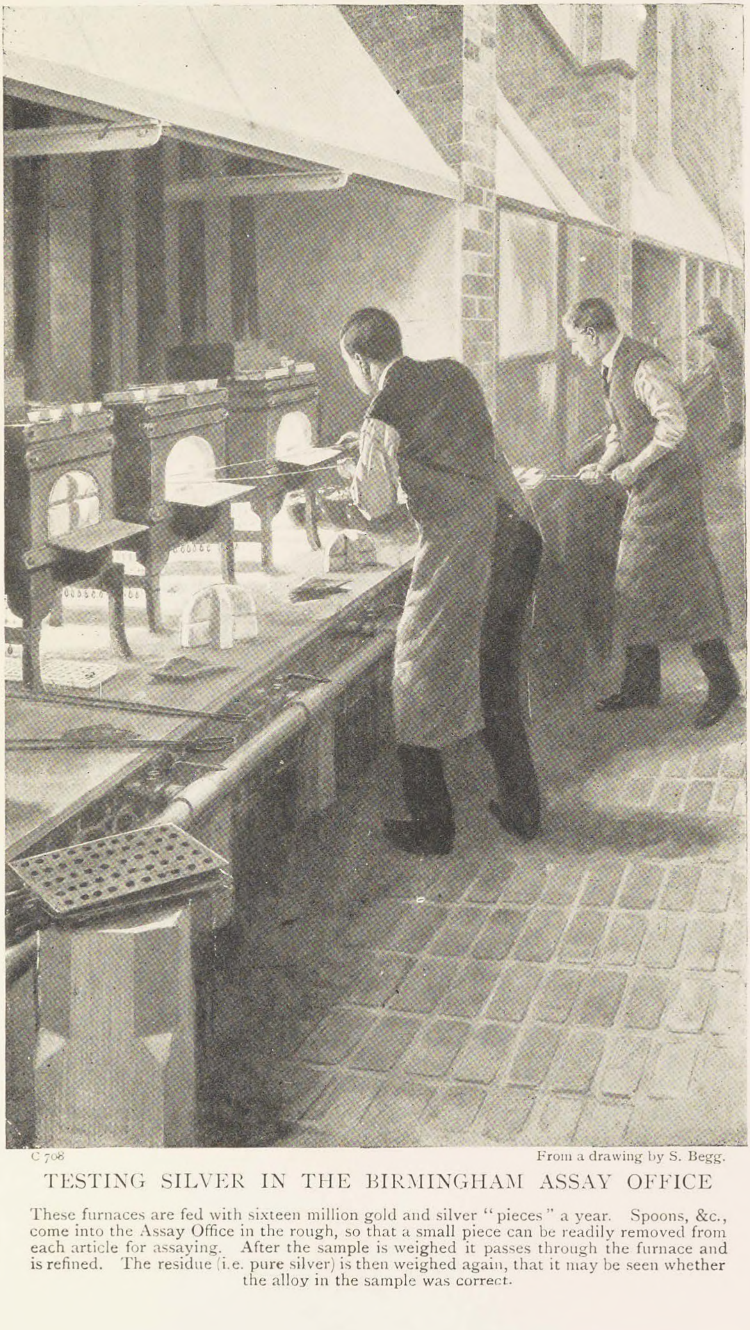
The mercury escapes as vapour, to be condensed again in a trough of water, while the silver remains in the retort.

The silver mines of North America, which are now so productive, were discovered quite recently. Silver was known to occur in and around the Rocky Mountains in 1859. In 1864 a party of miners were on their way to White Pine. They were, of course, out for gold, as no silver had been obtained in that district, and apparently it was not considered worth while for anyone to look for it. The way was long and the wind, probably, was cold; certainly the road was rough. Black sheep are in every fold, and in every company of prospectors some will be found who are less stanch and persevering than others; one or two of these laggards were daunted by the difficulties of the trail, and turned aside to find an easier way. They did not find it; in fact they did not trouble to, for they saw signs of rich deposits of silver. The district now contains no fewer than sixty flourishing mines.

Silver, with the exception only of gold, is the most easily worked and plastic of metals. It is useful to the chemist on account of its resistance to the action of caustic alkalis, and it is the best conductor of heat and electricity. But it is principally on account of its beauty and malleability that silver has attained its place amongst the world's treasures. It is a beautiful material, but cheap. Its value rises in accordance with the skill of the artist who fashions a lump of silver into a candlestick or a salver, while antique silver, as you know, commands fabulous

prices. The point to be learnt is, when does silver begin to be old? Not long ago a sale of silver was held at Christie's, the current price of raw silver being $28\frac{1}{16}$*d.* an ounce. Three gigantic candlesticks bearing the date 1853 were sold at 3*s.* 4*d.* an ounce, while a tiny goblet made just 200 years before fetched £32 an ounce. A Victorian dinner service, including 122 plates and every variety of dish known to butlers, and weighing 5057 ounces, changed owners for the sum of £758, 11*s.* 8*d.* This contrasts strangely with the price (£150) paid for one small silver-gilt spoon, dated at York 1615. We may take it that the age of silver begins to be of consequence from the time of George II. In point of beauty, the articles may not surpass, nor even approach, those made by modern silversmiths; but they are rare, and with the collector rarity counts for more than beauty. Moreover, the least romantic amongst us must admit that a goblet which touched lips now dead and gone and forgotten, a candlestick which held the light for dames with powdered hair and brocaded dresses, beaux in silks and laces, stern soldiers or intriguing politicians, all alike returned to dust, have a charm of their own. We are all children of the past and slaves to tradition, and as such we cannot forgo entirely our allegiance to our forbears, however much we may glory in the present and dream of the future. Listen to a true story which illustrates this perhaps better even than the wealth changing hands briskly at Christie's.

Once upon a time there was a miser. He was quite the orthodox kind of miser: old, in ill-health, apparently very poor but in reality very rich. Now



C 708 From a drawing by S. Begg.

TESTING SILVER IN THE BIRMINGHAM ASSAY OFFICE

These furnaces are fed with sixteen million gold and silver "pieces" a year. Spoons, &c., come into the Assay Office in the rough, so that a small piece can be readily removed from each article for assaying. After the sample is weighed it passes through the furnace and is refined. The residue (i.e. pure silver) is then weighed again, that it may be seen whether the alloy in the sample was correct.

it happened one day that, contrary to the usual custom of misers, this old man engaged some workmen to carry out some repairs in his house, which was a very ancient building. Probably he would not have spent any money if he could have helped it, but the floors were giving way under him as he trod, and so he was obliged to have them patched up.

The workmen arrived and set to work on the sitting-room floor. They blithely pulled up the rotten old boards, singing and whistling, no doubt, and in other ways doing violence to the feelings of the miser, who was sitting gloomily in his kitchen thinking of the bill. A few days later, however, one of the workmen asked the miser to come and look at something he had found, and produced a heavy lump of some metal encrusted with dust and dirt. This lump, and two similar lumps, they had found underneath the floor boards amongst a mass of rubbish and litter. The miser growled at them and grumbled at being disturbed and called them meddlesome fellows, but took charge of the three lumps and carried them off to his kitchen. Here he carefully cleaned and washed them, and found to his delight that they were undoubtedly of silver and that they appeared to fit into one another. Under cover of darkness the miser carried his find to a friend for advice. The friend said: "Oh, this is very interesting. It must be an Elizabethan salt. Send it up to Dot & Spot and ask them what they'll give you for it."

The miser, however, would not trust to the post, so he packed a bag and went off to London. Messrs. Dot & Spot whispered together when they saw the

lumps of silver, and finally they turned to the miser and said: "We will offer you £3000 for this." But the miser was too clever a man to show any surprise. He just took the salt out of the hands of Messrs. Dot & Spot and walked out of the shop. A few days later he had a letter from Dot & Spot offering him £4000. Then the miser packed another bag and went up to London, this time to see Messrs. Splash & Dash. When Messrs. Splash & Dash heard his story they said: "Yes, it is most interesting. See, here is Queen Elizabeth's private mark. We will give you £5000 for it." But the miser would not accept.

Within a week the miser was dead, and the story so far as he is concerned comes to an end. I hope, however, that he has left the salt to a poor but honest heir who will know what to do with his inheritance.

An Elizabethan salt, worth some £5000 or £6000, is removed far above a "tin" sauce-pan which you can buy for 6½*d.* Yet the 6½*d.* sauce-pan is of infinitely greater value to the community than Queen Elizabeth's ponderous salt cellar, which is only a thing to look at. The "tin" sauce-pans and the hundreds of odds and ends of "tin" utensils have done a vast deal to cheapen and sweeten the preparation of our food both in the kitchen and out of it. Please notice that I put "tin" in inverted commas. You couldn't get a tin sauce-pan for 6½*d.*, for tin costs about £160 a ton. The pots and pans in the kitchen that look like tin are really made of iron or steel coated with tin. The tin-plate industry is a very important one, and centres round Llanelly in South Wales.

Tin is one of the most ancient metals. There are

remains that show that tin was used more than 2000 years ago. This metal may indeed be called the foundation of Britain's trade, for its existence in Cornwall and elsewhere attracted to our shores the earliest traders of the Mediterranean. Tin has many uses, but the greatest quantities are absorbed in making alloys. Bronze, gun-metal, and Britannia metal are some of the alloys which depend on tin. You know, of course, the difference between an alloy and an amalgam? An alloy is a compound or mixture of two or more metals, while an amalgam is a compound of a metal with mercury. Bronze was the earliest-known alloy, and it is probable that the brass of the Bible was really bronze. Copper and tin, of which bronze can be made (though zinc, lead, and silver were often component parts of the Roman and Greek bronzes), were the first metals to be worked. Brass, on the other hand, is an alloy of copper and zinc, and in Biblical times zinc was too scarce to be used freely in alloy-making. Brass is harder and wears better than copper, besides being cheaper, so that it is of very great use in making parts of machinery.

All these metalliferous minerals are obtained by processes differing only slightly from one another. You will remember that in the first chapter I told you that metals were erupted from volcanoes in a molten state and that they cooled and solidified to form veins of metal running through strata of igneous rocks. But there are other ways in which deposits of metals have been formed. The metals, you see, which men discover and exploit nowadays have always been there. They were in existence when the world

was only a flaming ball of nebula. Vast quantities of precious metals may occupy the very centre of our globe still, but they are useless to us because we cannot get at them. There are plenty of metals within our reach, however, and it is interesting to learn how it is that they have stayed on the surface for the use and glory of man. Think of the interior of the earth, all hubble-bubbling and seething hot. Suddenly an explosion takes place, or there is an inrush of water, and this unquiet mass expands and forces roads for itself in all directions. Wherever it can find a crack it runs, not only in the form of molten rock but also in the form of steam and gases. Now you can guess what happens. By and by the torrent cools and condenses, and the cracks are filled with solid metal. The gases and fumes also cool and coat their cracks with metal in the same way as the chimney of the lead-mine becomes coated.

We sometimes find great beds of metals deposited on, or not far below, the surface. These cannot be accounted for in any of the foregoing ways, and we must look a little farther back into the world's history to find their origin. Long, long ago these beds were formed, when the outer crust of the earth first began to solidify. The particles of metal congregated together and cooled and hardened into an iron-field or a bed of copper. Our old friend segregation at work again. Rains and rivers then did the work of disintegration, and so it comes to pass that we find deposits of iron perhaps miles away from the parent bed. The sea off the coasts of Chili and Peru is impregnated with silver brought down by the rivers to such an extent

as actually to plate the copper sheathing of vessels which remain for any length of time in its waters. Now you can understand how it is that metal deposits occur in sedimentary rocks. The rivers brought the metal in solution to the great shallow seas of primordial times.

I hope that I have not, by any chance, given you the impression that the ores of the different metals pass straight from the mines to the smelting-furnaces. If the ores of such metals as lead, tin, copper, zinc, &c., were pure, such a simple procedure might conceivably be possible; but they never are pure. They are always accompanied by the rocks containing the veins from which they are got and by other mineral impurities, sometimes by other metals. And in these days the well-equipped mine makes good use of all its by-products. Many complicated mechanical processes have to be gone through before the ore is ready for the smelter. When it comes from the mine it is in large lumps, and the trucks containing it are run direct to machines which break it up into small pieces. There are many different patterns of rock-breaking machinery; some smash the ore up by the incessant pounding of huge jaws, others are rotary in action, and resemble gigantic coffee-grinders. When it comes from these machines the ore is further pulverized by being passed between heavy rollers, or under stamps that smash it with blows of colossal force. Next, since neither the crushers nor the stamps are able to grind all the particles of ore to the same size, it is passed through sieves having openings of gradually-diminishing size. The next process is one

of the most interesting in metallurgy, and consists in separating the particles of metal from the non-metallic minerals associated with them. This is made comparatively easy by reason of the different specific gravities of the various substances. Thus, if you shook into some water a mixture composed of grains of lead, zinc, and quartz, the lead, being the heaviest, would settle in a layer at the bottom of the vessel, the zinc on top of it, and the quartz on top of the zinc; and you would thus have three distinct and easily-separated layers. When the ores have been pulverized, they are generally separated on sloping tables called "buddles", though various machines—some of them of complicated action and construction—have been invented to improve and quicken the separation of the metals. Of course you will understand that the processes just described are all continuous, the ore being discharged from one machine into the next throughout its career.

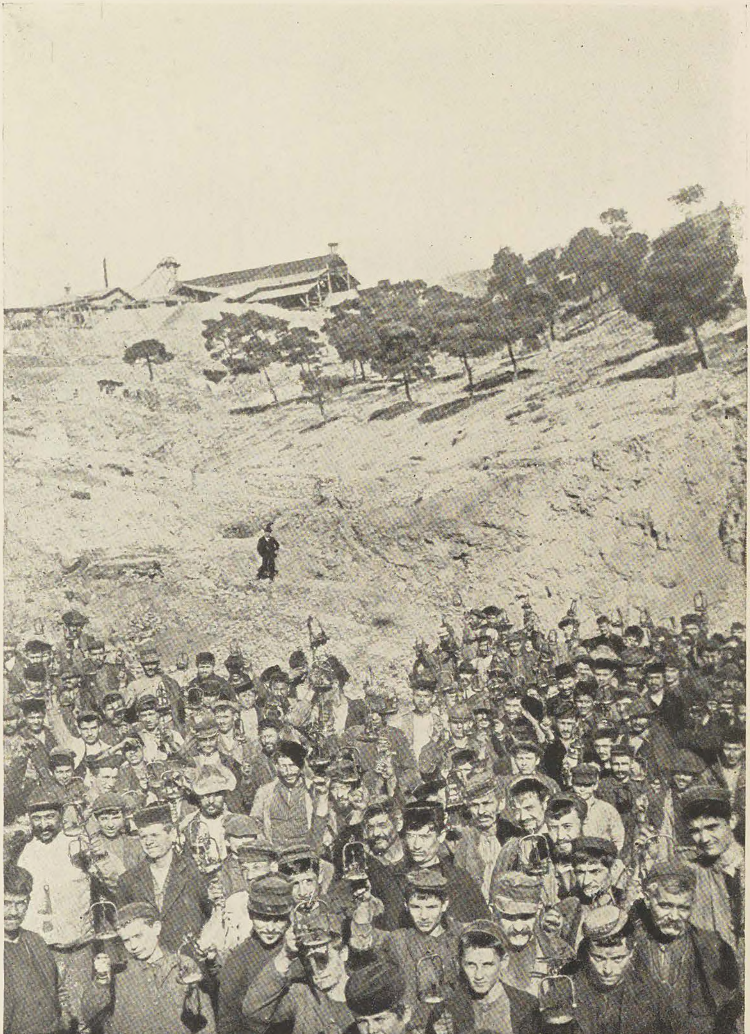
We come now to a very interesting metal—aluminium, a very common metal, yet one which, curiously enough, is quite "new", since it is only about half a century ago that it was isolated. Indeed, it may be said of aluminium that it is only now coming into use—slowly, cautiously, feeling its way very gingerly into a world scarcely ready to receive it. Its price has dropped about 300 per cent during the last forty or fifty years—dropped steadily as metallurgists have discovered more and more about its nature and its uses. Aluminium has a vast future ahead of it. We may even be standing on the threshold of an era in which the new metal will

largely take the place of copper and iron, perhaps even steel, in electrical and mechanical manufactures. That the Steel Age should give place to the Aluminium Age, is, I'll be bound, a possibility that has never occurred to you. Yet it is by no means an impossibility; for aluminium is everywhere—literally, it is as common as dirt. It forms something like 8 per cent of the crust of the entire earth. In the form of its oxide, alumina, it is one of the chief constituents of clay, and clay, as you have been told already in this book, is the accumulated dust or detritus of archæan rocks, such as granite and basalt. Now, such rocks as these are formed largely of felspar, and this felspar is composed mainly of alumina in combination with silica. Some forms of clay, such as the kaolin or china-clay, about which I shall speak in a later chapter, are composed almost entirely of alumina. Alumina itself has many uses in the arts. It is used to make the paints called *lakes*, for instance; but its chief value to mankind is that it is the main source of the element aluminium.

The useful properties of aluminium are so many that one is bound to wonder why it has been so slow in taking its place in commerce. It is a very beautiful metal, something like silver, and capable of being highly polished. It preserves its appearance better than any other metal except gold, and heat and cold, air, water, and acid have little or no effect on it. In a word, it does not oxidize as, for instance, iron does; and it has also a very high tensile strength, higher, indeed, than that of iron. One generally thinks of aluminium as a soft metal, like the silver it

so much resembles; but it can be made as hard as iron by hammering, and its malleability and ductility are further advantages. One misfortune is that it is difficult to weld; but this is an objection that metallurgists are busily striving to overcome. I am sure no one needs to be told that aluminium is very light; bulk for bulk, it is a quarter of the weight of silver.

There are several reasons why aluminium may one day take the place of iron and copper. In the first place, it exists in tremendous quantities all over the globe; and although it is an expensive metal compared with iron (when I wrote this it was selling at £80 a ton, Cleveland pig-iron at 52*s*. a ton), yet its cheapening is only a matter of time. At present, its preparation from the alumina in clay and other earths is rather a costly process. When the metal was first isolated it could only be obtained by the aid of long and complicated chemical reactions. Twenty years ago the Cowles electrolytic process was introduced, and the production of aluminium on a large scale became a commercial possibility. In the Cowles process the clay is mixed with charcoal and subjected to the intense heat of the electric arc. The heat decomposes the oxide and liberates the aluminium. Now, in connection with this process, I want you to notice a very important fact, and that is, that nearly all the large aluminium works are situated where there is ample water power. I can think of at least three works in such situations without going outside Great Britain. There is one beside the Falls of Foyers, that glorious Highland waterfall that many of you must have seen; and a far more ambitious



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SILVER-MINING IN GREECE

A group of Greek miners ready to go down one of the famous silver-mines of ancient Laurion. Note the prominent display of lamps.

scheme at Kinloch Leven, in Inverness-shire, where, by damming the mountain lochs, 30,000 horse-power is obtained in turbo-generators. And there is one in Wales, in the beautiful vale of Conway, not far from Bettws-y-Coed, to say nothing of hundreds more in America and on the Continent. The clay is not often treated on the spot where it is found, but is generally brought from a distance; and when once it is in the works electricity does the rest. There is no vast consumption of coal or coke as in iron smelting—no need to be near a coal-field.

To most people aluminium is simply a material of which very light and rather expensive cooking utensils are made; very useful these pots and pans are, too—good conductors of heat, clean and non-corrodable. But the metal has wider and greater applications than this. It is an excellent electrical conductor, and will one day be used very largely in electrical manufactures. And its lightness, strength, and tenacity make it very useful for boat-building. Torpedo-boats are now being built of it; and it is entering more and more largely into the making of aeroplanes, motor-cars, and machinery generally. I have said that it is only now beginning to come into its own; and when I add that when it is alloyed with a little copper it has a tensile strength higher than steel, you will be able to imagine how important a part it may come to play in the manufactures.

There is only one other metal that I am going to mention in this chapter, and that is mercury. And I am not sure that this is the right place to speak of it, since it has always been regarded as one of the

noble metals. It is queer stuff this mercury—the only metal that is fluid at ordinary temperatures. It has, too, other strange properties and a strange history. It is very old, historically. The Phœnicians and Greeks sought it in Spain, though I am obliged to admit that I haven't a notion of what use it was to them when they had got it. Theophrastus, the great Greek naturalist and philosopher, who taught in the third century B.C., and who wrote books on fire and stones, makes mention of mercury. The famous mines of Almada, in Spain, are said to be 2300 years old. We still get great quantities of mercury from Spain, and a lot more from California. It is nasty, poisonous stuff, beloved of boys in school laboratories on account of the interesting but rather fatuous experiments they can perform with it. It very seldom occurs in nature as a pure metal. It is generally mixed with sulphur in a form called Cinnabar, and is found thus in carboniferous rocks. The pure metal is distilled from the Cinnabar, which can be converted into vapour at a comparatively low temperature.

Mercury is much used in scientific instruments. You will know that, because of its power of expanding at a uniform rate throughout its mass, it is the most suitable material for thermometers. It has a very strong affinity for other metals, and forms the *amalgams* that are now largely used as a means of extracting gold and silver from their dross. It has recently been put to use in electric lighting; and it may be said for the mercury-vapour lamp invented by Mr. Cooper Hewitt that it is probably the most efficient form of electric lighting that has yet been

invented. In this lamp the light is given by the vapour of mercury made incandescent in a very hard vacuum tube. The mercury is burnt up very, very slowly—far more slowly than the ordinary carbon or metallic filament—and so the lamp lasts for a long time. It costs little to run; but it had great disadvantages in that its light was deficient in the red rays, and had an excess of the hurtful ultra-violet rays. It shed a horrible sickly greenish tint on everything when first I saw a demonstration of it a few years back; but I believe I am right in saying that the light has now been made neutral by the artificial provision of the necessary red rays, and that means are employed to absorb the excess of ultra-violet rays.

I have said that mercury was known to the ancients, and I professed ignorance of the uses to which it was put in those days. But reflection will supply to anyone at least one use to which it was wont to be put. Throughout the ages, from the days that marked the highest attainment of the Egyptians up to within a hundred and odd years ago, mercury has held a high place in the philosophy of the alchemists. We are apt to laugh at the followers of the "sacred art" and to think that all they ever did was to invent a meaningless jargon and a few conjuring tricks with which to impose on a credulous and easily-duped public. But the early alchemists, however wildly "unscientific" they may have been, did a great deal of sound spadework in preparing the way for the chemists and physicists who made the dawn of the nineteenth century so golden—golden in a sense not strictly alchemic. The Arabs, who learnt the funda-

mentals of alchemy from the Greeks, were the greatest of the world's chemical investigators for centuries. They held that there were three elements of which all other substances were composed, these elements being mercury, sulphur, and arsenic. They saw that mercury dissolved gold, the purest and most incorruptible of metals, and thought that gold and silver and all the metals were made of mercury and sulphur in varying proportions; and it was for the transmutation of these base metals into the precious ones that they sought and suffered. Although they groped on blindly, they found out many chemical reactions, and invented processes for bringing them about. It is indeed to the Arabs that we owe many words—such as alkali and alcohol—which show how keen was their interest in chemical science.

The dark days of the Middle Ages took from alchemy such common sense and inductive reasoning as the ancients had invested it with, and left only a meaningless quackery and imposture. It is true there are some really great names to be found among the alchemists of Europe between the twelfth and fifteenth centuries; but for the most part they were dealers in magic and spells, like the fellow whose acquaintance you made when you read Scott's *Antiquary*. These quacks carried alchemy to a degree of sheer nonsensical extravagance quite unknown in the days of the older "investigators". Professor Brown says: "Instead of useful work, they compiled mystical trash into books, and fathered them on Hermes, Aristotle, Albertus Magnus, Paracelsus, and other really great men. Their language is a farrago of mystical meta-

phors, full of 'Red Bridegrooms' and 'Lily Brides', 'Queen Dragons', 'Ruby Lions', 'Royal Baths', 'Waters of Life'. The seven metals correspond with the seven planets, the seven cosmical angels, and the seven openings of the head—the eyes, the ears, the nostrils, and the mouth. Silver was Diana, gold was Apollo, iron was Mars, tin was Jupiter, lead was Saturn, and so forth. They talk for ever of the Powder of Attraction, which drew all men and women after the possessor; of the 'Alkahest', or universal solvent; and the Grand Elixir, which was to confer immortal youth upon the student who should approve himself fit to kiss and quaff the golden draught. There was the Great Mystery, the mother of the elements, the proud mother of the stars. There was the 'Philosopher's Stone', and there was the 'Philosophical Stone'. The Philosophical Stone was younger than the elements, yet at her virgin touch the grossest calx (ore) among them all would blush before her into perfect gold. The Philosopher's Stone, on the other hand, was the firstborn of nature, and older than the king of metals." This trash is a fair sample of the wares of the mystic alchemists of the Middle Ages; and there are plenty of books available on the subject for those who have capacity for a larger dose.

CHAPTER V

From Mine to Dinner Table

You must all have read, at one time or another, the tales of the Brothers Grimm; and I hope you remember the story of the princess who told her father that she loved him as much as she loved the salt in her dinner. You will remember that the king was deeply offended with her for what he considered an unnatural remark, until one day the princess caused her father's dinner to be served without any salt at all. Then, of course, the king immediately recognized the truth and wisdom of her simile.

This story may or may not be true; you may believe it or not, just as you like. You must be prepared to believe, however, that salt was one of the first substances to obtain value in the eyes of man. Salt, in one form or another, is a necessity of life, and besides being a necessity it is a condiment that very few people would like to do without. It is said that depriving the victim of salt is a form of torture practised by the Chinese.

Of course, in the early days of man, salt was not a "treasure of earth". It was the fact that it could only be obtained from the sea-shore that gave it its market value. Maritime peoples had the monopoly of

the salt trade, and inland peoples were bound to come to them for supplies. The Greek word "hals" in the masculine means "salt", and in the feminine "sea", which clearly shows the connection in the ancient mind. The desire for salt has even been proved to have been responsible for the migration of whole tribes during the course of history. There are a few races who do not use salt in the crystal form, but they are amongst the lowest types of men, and provide their bodies with the necessary substance by drinking fresh blood. Nowadays the amount of salt used is beyond computation. London alone is estimated to consume 11 tons daily! It is therefore fortunate that the world is so well supplied with salt, and we need have no fear that the vast store-houses will ever be exhausted.

Where does it all come from? Well, to begin with, there are the seas—millions of cubic miles of salt-bearing water. Different seas contain varying amounts of salt, but the average percentage of salt in sea-water is calculated at 2.7. You must understand that when I speak of salt I mean what we generally call common salt, or chloride of sodium. There are many other kinds of salt in sea-water; for instance, chloride of magnesium, sulphate of magnesium (which we know more familiarly as the unpleasant preparation Epsom salts), sulphate of lime, and many others. Glauber's salt—sulphate of soda—occurs in large quantities in the Great Salt Lake, no doubt to make up for the absence of Epsom salt in the water. The composition of the water varies even in different parts of the same sea. The Caspian Sea itself is not quite so

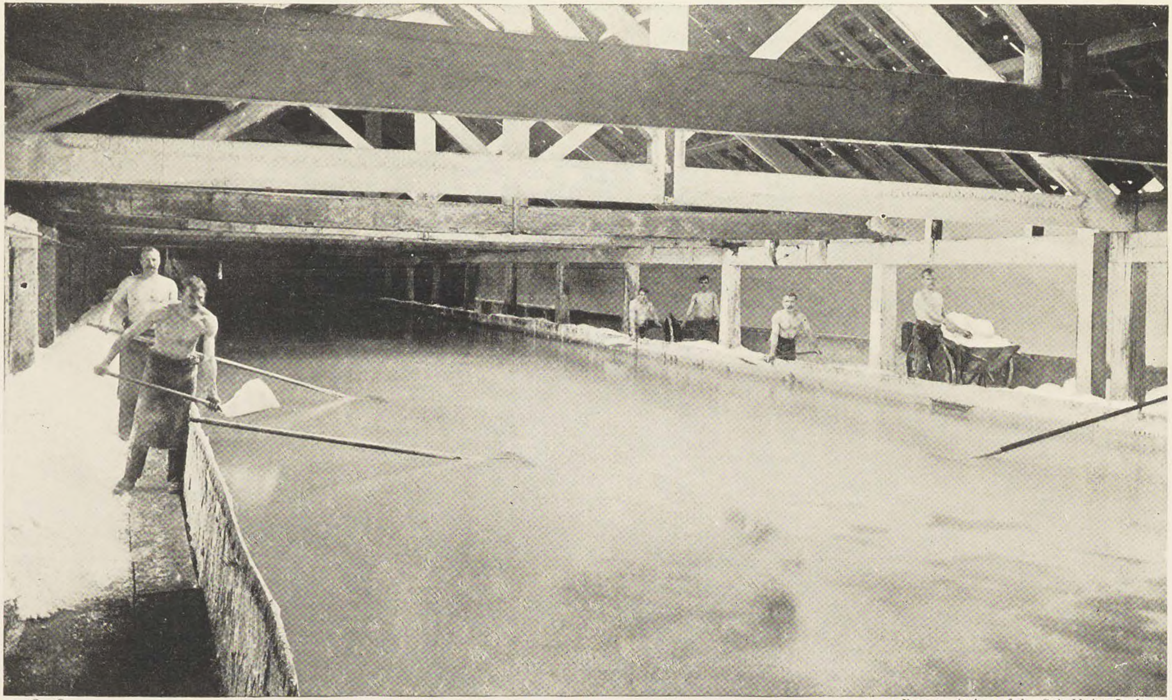
salt as the Mediterranean, but the Kara-Barghas, a branch of the Caspian, is so salt that its banks are quite devoid of vegetation, while another branch of the Caspian, the Karasu, is even salter, the salinity reaching 5.7 per cent. The reason for this is that the shores of the Kara-Barghas and the Karasu are so shelving and the waters so wide and shallow that these inlets act as natural salt-pans; the hot sun rapidly evaporates the water on the shores, and a deposit of salt is left. Meanwhile the evaporation is immediately made good by the rivers, which bring with them salts in solution, and so the process goes on. All rivers are constantly pouring salt into the seas, so that, however busily we may prosecute the business of making salt from sea-water, we are not likely to exhaust the supply. It is estimated that rivers bring to the ocean 6524 cubic miles of water every year, a formidable amount, of the greatness of which the average mind has no conception. This water contains, amongst other things, 160,000,000 tons of salt. Now, the consumption of salt for the whole world, at a modest computation, is 17,000,000 tons—it is probably more than that in reality—but in any case there is enough and to spare in the sea, supposing there were no other sources whence we could obtain it. In reality the ocean contains 144,000,000,000,000 tons of salt, a sum at which "imagination boggles". From these figures some geologists have tried to settle that vexed and vague question—will it ever be settled?—of the age of the earth. They make it reach 90,000,000 years; but as the results of different geologists from different

data vary from 20,000,000 to 140,000,000 years, it is plainly a subject on which the unscientific should keep an open mind.

But when we talk of the rivers carrying salt to the ocean, we must remember that they are only fulfilling Dame Nature's command to "pay back". All salt originally came from the sea. We are so accustomed to the present state of things, to our own maps and the existing divisions of land and water, that we find it difficult to realize that our paltry few thousand years of history are as but a day in comparison with the ages that have passed and gone. We walk through a fertile valley and admire the spreading fields divided by the winding river and the swelling hills on either side, but we do not trouble to enquire how long that river has been at work wearing away the rocks, grinding them into light fine soil, and gradually sinking its bed until it has formed the wide valley we now see. If we climb the hills and examine the rocks which form them, we shall probably find traces of marine life, and we shall know that at one time or another the land on which we tread was covered by the sea. The movement of the sea has been one of the main factors in forming the earth's crust. It is not definitely known how often the positions of land and water have changed places since their final separation, but it is established beyond doubt that many other continents and many other oceans had occupied the earth and vanished again before the coming of the first man. Not least among the results of these movements we must count the making of salt. We can still trace the beds of some of these transitory

oceans. For instance, at one time, there can be no doubt, the Caspian Sea and the Black Sea were one, for the same shells are found in both seas to-day, while the intervening land is broken up by salt lakes and marshes, and bears remains of similar shells. Again, we cannot explain the presence of seals in the Caspian Sea so far south of their usual latitudes, and the existence of a chain of salt plains and salt lakes in the east of Russia, without admitting the probability that the Caspian was connected with the Arctic Ocean. The Great Salt Lake of Utah, however, does not owe its salinity directly to the ocean. After the ocean had receded, North America possessed several enormous sheets of fresh water. One of these, which geologists term Lake Agassiz, has dwindled and shrunk until only a few scattered sheets of water remain to prove that it ever existed. Two other great lakes which drained into the Pacific have disappeared entirely but for the Great Salt Lake. Of course, a certain amount of salt was present although they were fresh-water lakes, and as one lake diminished in size the salinity became more and more highly concentrated, until at the present time the water is so salt that to sink in it is practically impossible; while the other lake dried up altogether, leaving vast deposits of salt in the desert.

The Dead Sea is extraordinary, partly on account of its depth below the level of the Mediterranean—nearly 1300 feet—and partly on account of its richly-deserved name. It is terribly salt, but not with the saltness of our friend sodium chloride; the chief offending constituent is chloride of magnesia. The



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By permission of the Salt Union Ltd.

DRAWING COMMON OR BROAD SALT FROM THE PANS

These pans are wide, shallow receptacles beneath which great fires burn. Crystals form and presently sink to the bottom. These are raked out and put into tubs to drain for half an hour, at the end of which time they have caked into a solid lump.

salinity of the Dead Sea is more than eight times that of the ocean, and it is no doubt on that account that no fish will survive in its waters and no vegetation can live on its banks.

In the British Isles the process of making salt from sea-water is no longer practised to any extent, as the discovery of the extensive salt-mines in various parts of the country has made it unnecessary and unprofitable; but at one time our sea—or bay—salt supported a flourishing industry. Hayling Island was for centuries famous for its salt, even so long ago as the days of St. Augustine, who is reported to have thought very highly of it. The primitive method of salt-making was very simple. Men made shallow artificial ponds by the sea-shore, into which they could let the water flow at high tide. No doubt this was principally done in the summer months, when the sun would be hot enough to evaporate the water rapidly. By degrees this process has been developed and improved until the highly-scientific salt-pans, or salterns as they are called, of Southern Europe have resulted.

We do not pretend as yet to have discovered all the earth's secret stores of salt, but we know of enough to supply all our needs for centuries to come. Distributed over the earth's crust are 325,000 cubic miles of rock-salt, just about a fourteenth part of the amount existing in the ocean. These salt-beds are found at varying depths below the surface, and may have been formed by successive inundations of the land by the sea. In some places they can be worked by means of shafts and galleries; in others, mines have to be

sunk and regular mining machinery employed. In our own salt-beds in Cheshire and the neighbouring counties and Durham the salt is procured in the form of brine. These beds are remarkable for the strength and purity of the salt they produce, and it is to this fact that the prosperity of our alkali manufactures is due. For salt is used in a number of ways of which we never think. The cook who throws a teaspoonful into the stock-pot and a pinch into the plum-pudding is one of the least important of the salt users of the country, though doubtless she would not be pleased if you told her so. If the salt supply were suddenly to cease, cook would have no salt for the multitude of purposes for which she now uses it; she would have no carbonate of soda for making her little scones, no washing-soda for washing up the dirty dishes: the washerwoman would have no more soap; the gardener would have no more glass for his frames; the dyer and bleacher and wool-scourer all would have to shut up shop; I should have no more paper to write on; and very soon we all should be dead. It sounds like the old woman's tale: "Pig won't get over the stile and I shan't get home to-night!"

Sometimes the brine rises to the surface naturally in the form of a salt-spring. Brine-springs have been in existence and have been worked in Cheshire since very early times, though there are now no natural springs there. Mention is made of them in the Domesday Book. But it was not until 1670 that some men who were digging for coal accidentally found the bed of rock-salt at Northwich. This mine

lies at a distance of 35 yards below the surface. Above the salt and in the hollows of the bed lies a subterranean lake of strong pure brine, which is pumped up to the surface and evaporated to form the Cheshire salt, which is justly renowned for the fineness of its crystals and its whiteness. All our British brines are sea-green in colour, and owing to their freedom from impurities are inexpensive to evaporate. The more foreign matter that is suspended in the brine the longer the salt takes to crystallize, and consequently the more fuel is used. In the Cheshire mines which do not occur very far below the surface the method employed is practically the same in every case. A hollow rod or pipe of copper or iron is pushed down into the brine, which rises to a certain height in the pipe of its own accord. A pump brings it to the surface, and it is then run off into reservoirs. Thence it flows into pans which are built on a lower level than the reservoirs. These pans are wide, shallow receptacles, beneath which great fires burn. Presently the brine begins to hiss and steam, and crystals begin to form on the surface. These float about for a short time and then sink to the bottom of the pan. About every ten hours the crystals are raked out of the pans and put into tubs to drain for half an hour, at the end of which time they have caked into a solid lump. The lump, if it is to turn out the best fine salt, is then dried in an oven; if it is not stored it makes what is called butter or cheese salt. Brine boils at 226° F.—fourteen degrees higher than water; "common" salt crystals form at 165° F., large-grained salt at between 130° and 140° F., and fishery

salt at 100° to 110° F. The largest-grained salt is obtained by leaving the crystals in the brine for about a fortnight.

Since the brine is produced by washing away the rock-salt by water, you will be prepared to hear that the industry has its disadvantages. "Constant dropping wears away a stone", and continual washing will ultimately dissolve the largest soluble rock. When this rock is the bed on which a whole town stands, disasters may be expected to follow. In a mine timber supports prop up the undermined rock, and in salt-mines pillars of the salt itself are sufficient to hold up the overlying country; but no one can go down into a brine-well to investigate and repair the damage done by the little stream of water which is rising gently but constantly to the surface, carrying with it the rock through which it has flowed. But the amount of erosion can be estimated, and how much do you think Great Britain is said to lose in a year from this cause alone? No less a piece of ground than 64 acres! But nobody can prevent it so long as the brine-pits are worked, and it would be a national calamity if they were to cease. If ever you go to one of the salt towns of Cheshire you will wonder if after all you had not right on your side when you used to draw those queer houses years ago when you were quite a little boy. Of course they were pictures of Northwich houses. What matter if your house did lean to one side? What matter if the door were aslant? What matter if the chimneys leant over to look in at the skylight? What matter if the roof did bend in the middle? It was a Northwich house, and abso-

lutely true to life. Sometimes the houses disappear altogether through a neat little crack in the ground. Existing lakes and pools of water suddenly drain away, while new ones as suddenly appear. Unless I am much mistaken, there are shown at Droitwich, a pretty little Worcester spa that deserves to be better known, some houses that have sunk so low in the world, literally speaking, that they have to be entered by the bedroom windows—at least, they would be so entered if the owners had not thoughtfully provided front doors where the bedroom windows used to be. At any rate, the ground-floor has become the cellar (goodness knows to what Plutonic depths the original cellars have descended), and the simple souls of Droitwich receive their letters, or the morning milk, merely by turning in their beds and stretching forth their hands.

Another important salt district of the British Isles is in Durham. Here the salt is unusually fine, and from these beds some of the best table-salt is obtained, but it occurs at a great depth below the surface, and has to be procured by special methods. You will understand that in Cheshire water from the surface is constantly percolating through to maintain the supply of water in the pools of brine. But the Durham beds lie beneath 1000 feet of hard earth, through which no surface water can find a way. A bore-hole has therefore been made, piercing the earth as far as the top of the salt-bed. Inside this bore-hole is a small pipe which goes right through the salt-bed. We can imagine what a cross section would look like—an outer ring, which is the bore-

hole; an inner ring, which is the pipe; and a space between the two. This space serves as a channel for water, which thus runs down until it reaches the top of the salt-bed. Here the bore-hole ceases, but salt being a soluble rock the water trickles through it, and by the time it reaches the bottom of the bed it has become brine. This brine begins to rise of its own accord in the pipe, and by the use of the pump it is brought to the surface. Here it is run off first into a filter-bed, and finally reaches the evaporation pans. After being dried for seven or eight days the crystals are still not considered quite fine enough for the best table-salt, so they are now ground by machinery, sifted, and put up into bags. But our table-salt has to have other ingredients besides plain salt. If nothing but salt were used it would soon damp and cake and lose its fineness. Salt that has lost its fineness is like a razor that has lost its edge; it is of no use. The finer the salt, the stronger are its properties. So at this stage of the process the salt receives its final improvement; that is to say, a small percentage of three different phosphates is added to it—precipitated phosphate of lime, phosphate of soda, and phosphate of magnesia. These phosphates add to the food value of salt, but do not believe the advertisements which tell you that "So-and-So's Salt is a Perfect Food". It may be a perfect condiment, but with no degree of truth can anybody's salt be called a food.

Other very important brine pits exist at Stassfurt in Germany. These pits were first worked many years ago, but the brine was so heavily laden with

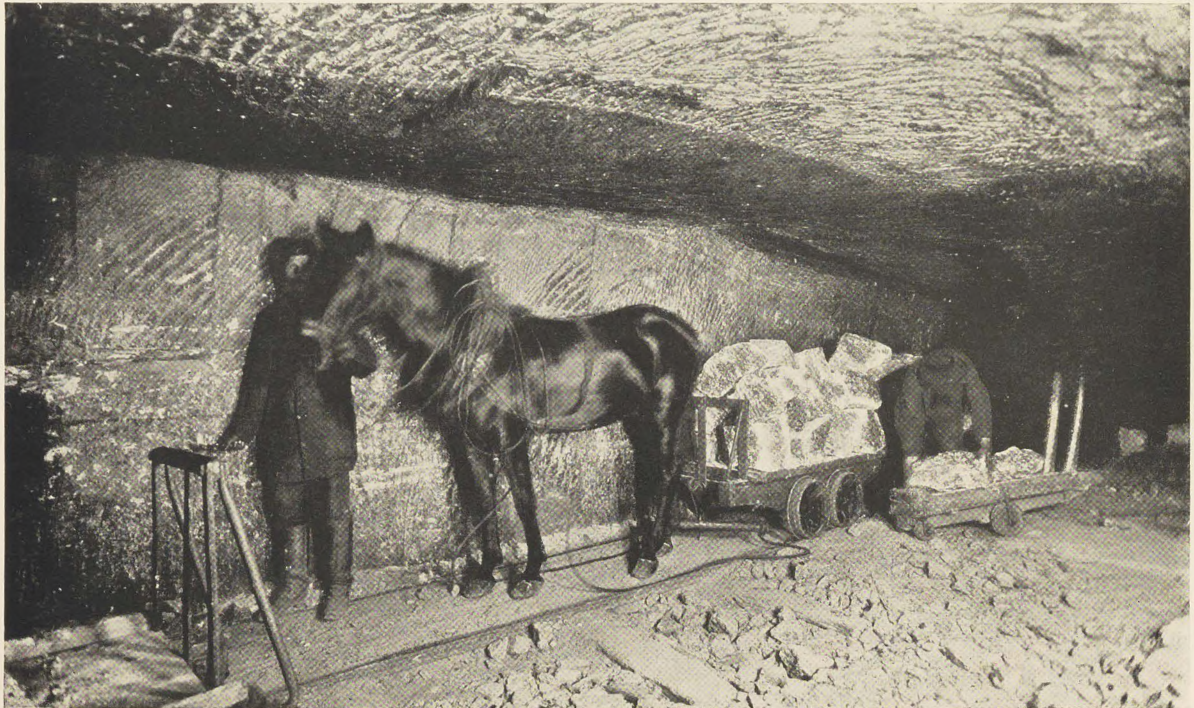
salts of potassium that the industry was hardly profitable. In those days men who were out to find salt wanted salt, and did not see the use of anything else. It was not until 1860 that it occurred to the superintendent of the mine that potassium might have some value, but immediately he conceived the idea he set to work to investigate it. The result was, he discovered the wonderful fertilizing power of potassium, and in the next year a factory for its manufacture was established. Now the Stassfurt potassium is of far greater importance than the Stassfurt salt, and is practically a monopoly of the government.

To revert to the subject of fairy tales, you will remember how very often the good or evil genius of the story would take the hero or heroine to some magic palace underground. How firmly the idea of goblins or other fairy creatures dwelling in the bowels of the earth impressed itself on our childish minds, and on childish minds before our day, centuries and centuries back! If this were the time and place for a disquisition on folklore I could no doubt spin you an interesting yarn on the similarity of fairy tales of all nations and their agreement with the facts of the workaday world; but it is not, and we can therefore only glance at the subject from the point we have reached. We stand, as it were, on a pinnacle overlooking surrounding country which beckons and lures us to explore it, but we may not turn out of our way. The plains may be fairyland, but our pinnacle is of salt, and we must keep to the salty path that stretches before us. But the fairy tales were so far right. There is a fairy palace underground, and a city where

strange and unfamiliar creatures spend their days. Where? Well, a good way off, but if we meet the jinns or the troll, or whoever it is that is going to conduct us, the journey will be easy.

Here he comes. Take hands and away we go! Whoop! Over the sea. That was the Straits of Dover. How the search-lights from the war-ships seem to follow us, and what a blinding flash comes from the lighthouse at Cape Grisnez! . . . That was Paris, where all the lights twinkle like jewels. On and on, over the dark country; here a village, there a town, now a gleaming river, now a lofty mountain; then the railway like the trail of a monstrous slug, and now, here we are on firm ground once more. Two stamps of the genie's foot and down we go, down, down, down, till our hearts come into our mouths and our hair stiffens with fright. Where are we? Why, according to the map I suppose we are in Galicia, that great little-known country between Russia and the Carpathian Mountains; and the little town that we saw just before the genie stamped his foot and took us underground rejoices in the name of Wieliczka, which I cannot pronounce. But we do not need to be so explicit. All that interests and excites us just now is the thought that we are on our way to the only magic city of the goblins that human beings are ever likely to see.

The goblins have been at work here for nearly 700 years, but as they would not like to be called goblins, we must give them their proper name of Poles. These men would seem almost as strange to us as goblins, I dare say. In appearance, habits,



HORSE-TRAMWAY IN THE WIELICZKA SALT MINES

It is pleasant to realize that the horses, which are located in spacious stables, thrive well in their underground dwellings. Theirs is a better lot than that of the "pit ponies" in coal mines.

and customs they are absolutely different from Britons. For instance, do you know any British workman who would consent to pass eight hours of every day in a salt mine for the wage of a little less than a shilling? Yet that is what these Polish miners do. Some of them are born there, live and die there. Let us take a little walk through this wonderful place.

At first we are half-dazzled by the glistening walls, floor, and roof, illuminated by countless electric lights, but by and by our eyes become accustomed to the glare. We will walk along one of the principal streets first of all, and notice the outsides of the houses and buildings before going inside. A tramway runs along this street, the trams being drawn by little ponies that have never known any other home. Presently we come to an open space where the principal streets and tram-lines meet. Here is a wonderful building, elaborately carved out of the salt and lighted with rows of brilliant lights. This is the central station, the terminus of the 22 miles of railway in the mine. It is as convenient and well-equipped as any other terminus you can think of, having spacious waiting-rooms, and offices, and a refreshment-room of which it can *not* be said, as the Boy said of Mugby Junction, "and what's proudest boast is, that it never yet refreshed a mortal being". In fact it looks more like a summer pavilion than a railway station, with its latticed galleries and stately pillars, gleaming white and iridescent. This, of course, is a comparatively modern addition to the buildings in the mine, and, being purely a utilitarian structure, it has been carried out

in a perfunctory manner. For the highest expression of the miners' art we must go to their chapels. Their religion is so much a part of the miners' lives that for centuries they have been at work hewing out chapels from the rock, and in their spare time decorating them with magnificent carvings. One statue, in an excellent state of preservation, is that of the Archangel Michael, dating from 1691. The chapel dedicated to St. Anthony was excavated by some poor untaught man, whose name has not been preserved, 200 years ago. It contains three altars, all of which are objects of beauty in themselves, and beside each of which are grouped figures of saints. The pulpit is supported by statues of St. Peter and St. Paul. The statue of King August II, which stands near the main entrance, is a wonderful piece of execution. In days gone by services were held regularly in this chapel, but now only the modern chapel of St. Cunegund, the patron saint of the mine, is used for worship. To reach St. Cunegund's we have to go down forty-six steps hewn out of the salt. It is of good proportions, being 150 feet long, 45 feet wide, and 30 feet high. Round the walls are ranged statues, and the pulpit is a veritable work of art. Here, as in most of the other public buildings, the lighting is carried out by means of chandeliers and candelabra made of crystal salt. These are "lustres" indeed worthy of the name. Now we come to a ball-room fit for a king's pageant. Here are held all the miners' festivities. The opening of a new working or the closing of an old one is signallized by a ball. The miners have no lack of partners,

for their mothers, sisters, sweethearts, and wives all turn out in their picturesque costumes to dance to the wild music of the miners' orchestra. This orchestra is ready to charm the visitor at all the principal points of interest (for, alas! romance as we may, we cannot quite hide the fact that the mine is a happy hunting-ground of the tourist and the professional guide); and the music gives one a wonderfully fairy-like, unreal feeling. The sound of the violins wails along the galleries, now soft, now swelling and increasing, then dying away again, as we walk along the winding roads.

But our weirdest experience is yet to come. So long as we were walking and felt the grit of the earth beneath our boots we were, in a sense, still at home. We knew at any rate that we could trust our feet to take us along. But we cannot resist the smiles and wiles of this dark-faced man who has attached himself to us. We cannot understand his words, it is true, but we cannot fail to understand his meaning. He wants to take us on the lake.

To venture on a lake 700 feet under the earth, do we dare? Yes, we do, most certainly; though probably we feel an unconfessed chill come over us as we step on board and look down at the thick, dark water. It is unlike any water we have ever sailed on before, and what a heavy, ominous *swish* it makes against the sides of the cavern! We are glad to see that the boat is large and substantial: not that there could be any danger of drowning in this thick brine, but just imagine what it would be like to get a mouthful, or one drop in your eye! Besides, we cannot

quite get rid of the creepy feeling, the idea that there may be *things* in the water, things with claws and teeth and horrid faces. But it is too late to change our minds. The boatman cries, "All is ready!" in his strange, outlandish tongue, and the cavern and the water take up the sound and toss it backwards and forwards, until we might think it the voice of a giant. Our trip takes twenty minutes, and, greatly to our surprise, we have no adventures. But we shall know now, at any rate, what the Styx looks like, though we cannot by any stretch of imagination compare our urbane conductor with Charon. There are sixteen of these lakes in the mine, but visitors are only allowed to go on this one.

There is another aspect of brine which we have yet to consider. There can be no doubt that the natural springs of brine which occur in this country and in certain other parts of the world have proved veritable treasures to those who owned the land in which they were found, not on account of the commercial value of the constituents of the water, but on account of their curative properties. At Droitwich much of the prosperity of the town is due to the visitors and invalids who flock thither for the purpose of taking the baths. In this connection we may mention the springs of Bath, which are amongst the most famous in the world. These springs, like those of Matlock and Buxton, are known as thermal springs, owing to their high temperature. Among other famous thermal springs are those of Vichy, Ems, Carlsbad, Wiesbaden, Baden-Baden, and Aix-la-Chapelle. The waters at Salzbrunn, Homburg,

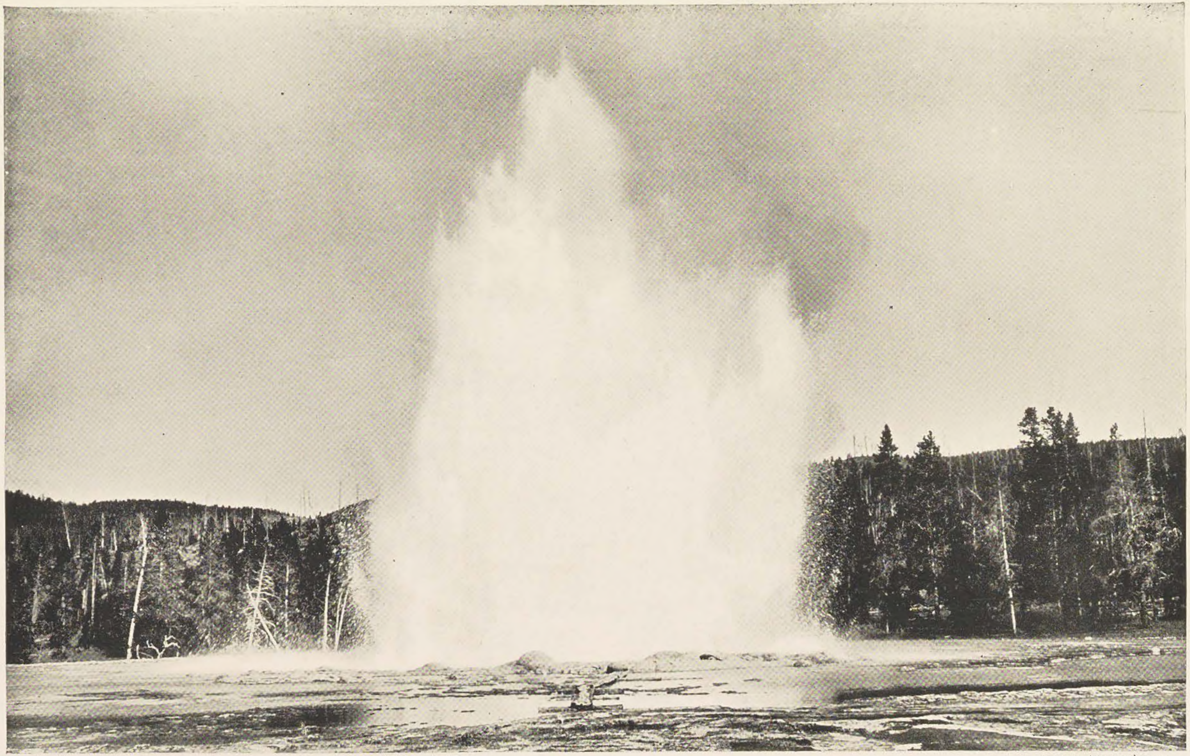


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Photo. Photochrom

THE GREAT FOUNTAIN GEYSER, YELLOWSTONE PARK

This is the most magnificent of all the geysers in the great American National Park. It is of unusual formation, for no cone or mound is found at its mouth—only a large peaceful pool. Suddenly there comes a series of discharges of boiling water, 150 feet in the air, which disperse in a beautiful rainbow spray.

Cheltenham, and Harrogate are cold. Of course, the qualities of the water are determined by its locality and the strata from which it flows. As a rule hot springs come from a great depth under the earth. It has been estimated that the springs of Bath start some 4200 feet below the surface. Sometimes, however, the water is heated, not by the ordinary constant heat of the interior of the earth, but by volcanic action. This is the case with the marvellous geysers of North America, Iceland, and New Zealand. One of the wonders of the world which we all ought to try to see before we die is the Yellowstone Park of America. This great tract of land, of over 5500 square miles, is preserved as a kind of natural museum and zoological gardens. Here animals, birds, and fishes may all live and thrive without fear of molestation from the most hardened collector. But more wonderful even than the rarest beasts are the geysers. There are over a hundred geysers in Yellowstone Park, and over three thousand thermal springs. Many of the geysers are distinguished by names more or less indicative of their natures. Thus we find "Excelsior", which flings a column of water to a height of 300 feet about every seventy-five minutes. The "Giant" and "Giantess" are also geysers of great power, while the "Miniature", as might be expected, is the smallest known, and though a busy little spouter, cannot lift its water higher than 1 foot. "Old Faithful" is almost as dependable as Greenwich time, but unfortunately he "strikes" every sixty-five minutes instead of every sixty. He has

been "going" for at least thirty years without once needing repairing or winding up. A most descriptive account of the banks of the Fire Hole River is given by Lord Dunraven in his book *The Great Divide*:—

"Its banks and beds, entirely composed of hot-spring deposit, are honey-combed, split up, and scooped out all over by geysers, springs, and pools, simmering, murmuring, gurgling, grumbling, spitting, snarling, steaming, hissing, exploding, boiling, and roaring—in short, making every sort of extraordinary noise. Some grumbled quietly along, as if enjoying themselves pretty well, breaking out occasionally into a sort of gurgling, explosive laughter. Others, after being quiet for a long time, got into a violent rage, spat or snarled, or hissed like angry geese."

The largest geyser in the world is in New Zealand, but it has not the beauty of those in Yellowstone Park. Its water is thick and muddy, whereas that of the Yellowstone geysers is invariably clear and limpid, while its mineral constituents, when precipitated, form layers and cones of wonderful shapes and colours. The colours are often due to algæ which flourish in the hot water, but sometimes, as in the case of the "Castle" geyser, the deposit is pure white.

In districts where springs of very hot water occur, it is not surprising to find that the inhabitants make good use of this natural supply. It is said that at Chaudes-Aigues, in France, "wooden conduits, erected in all the streets of the town, supply on the ground-floor of each house a reservoir which serves to heat it during cold weather, and thus dispenses

with fires and chimneys. In summer, small sluices, placed at the entrance of each conducting tube, stop the warm water, and throw it back into the rivulet which flows at the bottom of the town." I have never been to Chaudes-Aigues, so I shall not vouch for the accuracy of the foregoing statement. But I do know that if you want seriously to frighten a French sheep you have only to say to it "Chaudes-Aigues". It is a tragic place for sheep; their fleeces are sent there in thousands because the waters have the property of cleansing them from grease.

One word more. The minerals in solution which occur in all water are necessary to support life. A spring of practically pure water occurs in the Austrian Tyrol, at Gastein, but it has earned for itself the name of Poison Spring, from the harmful effect it has on those who persistently drink it.

CHAPTER VI

The Oldest Art: Making China and Glass

" . . . the city of Tin-gui.[1] Of this place there is nothing further to be observed, than that cups or bowls and dishes of porcelain ware are there manufactured. The process was explained to be as follows: They collect a certain kind of earth, as it were, from a mine, and laying it in a great heap, suffer it to be exposed to the wind, the rain, and the sun for thirty or forty years, during which time it is never disturbed. By this it becomes refined and fit for being wrought into the vessels above mentioned. Such colours as may be thought proper are then laid on, and the ware is afterwards baked in ovens or furnaces. Those persons, therefore, who cause the earth to be dug, collect for their children and grandchildren. Great quantities of the manufacture are sold in the city, and for a Venetian groat you may purchase eight porcelain cups."

So says Marco Polo in the account of his travels in the thirteenth century. The centre of the industry is no longer at "Tin-gui", but at King-te-ching, in the province of Kiang-si. A range of hills in the neigh

[1] The modern Ting-cheu, in the province of Fo-kieu.

SOME EXAMPLES OF DECORATIVE POTTERY

Lancastrian, Bernard Moore, and Ruskin Ware at Messrs. Osler's, Oxford St., London. The true secret of porcelain-making was obtained from converts by Père d'Entrecolles, the Superior of the French Jesuits in China. Information sent home by him resulted in the setting up of the famous manufactory at Sèvres.

bourhood of King-te-ching has given the name kaolin to the fine white clay used by makers of the best porcelain. Porcelain is so called on account of its resemblance to the smooth, shiny surface of the cowrie shell (*porcellana*), and the reason why we call all pottery ware by the generic term of "china" is not far to seek. The Chinese were the first of all nations to discover the art of making porcelain. They were producing fine china while the Greeks were still content with pottery—that is to say, about 200 B.C.

Making pottery was one of the earliest of man's handicrafts, or, to be exact, of woman's handicrafts. Let us give woman her due as being the originator of the domestic arts. As soon as fire came into use, woman began to cook. No doubt it was woman who first built her fire on a little hearth of clay, and sooner or later she would be bound to notice how the clay hardened under the action of the heat. Possibly her man took a dislike to fish flavoured with ashes and smoke, and to please him she tried a new way of cooking it. Instead of placing the fish directly over the fire, she wrapped it first in a covering of wet clay. Man ate, and graciously approved, so woman persevered and built the first oven. From ovens, pots and vessels were but a step; and what an economy was effected by breaking up and boiling the bones into soup, though they were previously well picked, we may be sure! We must turn the pages of centuries in the book of time before we find any appreciation of the decorative value of pottery. Woman, no doubt, made vessels for holding her little stores: a hand-

ful of much-prized salt, perhaps some milk, and possibly honey. The Assyrians made bricks 4000 years ago, while the Egyptians produced a beautiful glazed pottery in 1600 B.C. This pottery attained a great popularity amongst the nations with which Egypt traded, for traces of it are found in many countries. They made a great variety of articles, such as figures of their gods, birds and animals, scarabæi and vases. Many of those objects, sometimes more curious than beautiful, which nowadays we dignify with the name of vase, bear little resemblance to their remote ancestors made by the Egyptian potters. Vases originally were a kind of adaptation of the human figure. The neck and lip stood for the head, the main part for the trunk, the base for the feet, and the handles for the arms. The Greeks produced pottery of beautiful shape and ornamented with graceful and delicate patterns. They had only the commonest materials, and until about 600 B.C. had produced nothing better than the rudest earthenware. Then they suddenly began to improve their work, and invented first a glaze through which they could scratch a pattern on to the ware. The vase being of one colour, and the glaze of another, a variety was thus obtained which they were not slow to improve upon. They soon found means of applying other colours, and next they began to cover the rough clay with a thin coating of fine smooth clay. This covering was called an "engobe". The next and last change marks the climax of art in Greek pottery. Instead of tracing the patterns in black or colours they now blackened the whole of the body of the vase,

leaving the design in the natural clay. Details were put in with fine lines, generally in white. It is sad to have to relate that the Greek potters did not keep up the high standard of their work. They began, I suppose, to pander to the vulgar-minded public. Instead of decorating their vases with beautiful drawings of noble men and graceful women, they began to crowd unnecessary figures into the scene, to introduce excessive and meaningless ornamentations and to choose stupid and inartistic subjects. Even the proportions of the vases themselves suffered, and became as exaggerated as the monstrous productions of the "Nouveau Art" of our own day.

The industry now proceeds sluggishly for more than a thousand years. New processes develop and die down again, but the cursory glance we are directing towards the history of pottery cannot take in all details. You have not forgotten that the Egyptians discovered a glaze, and the secret had been handed down to Persians, Arabs, and Moors. It was not until these nations began to meet and mix with Europeans in the early Middle Ages that the art became a general one. In 1309 the island of Rhodes fell into the hands of the Knights Hospitallers of St. John, who established there a colony of Persian potters. These workmen produced a kind of pottery having a bright enamelled surface, and specimens of "Rhodian" ware have now a high value. At the same period the Moors founded the manufacture of Hispano-Moresque enamelled faience in Spain and the Balearic Isles. The Italian "Majolica" is a development of that produced by Majorca. This

Majolica pottery is covered with a tin enamel. The most famous examples are known as Gubbio ware. They were made by Maestro Giorgio, who lived and worked at Gubbio in the early part of the sixteenth century. Catherine de' Medici introduced the art of enamelling pottery into France, but an enamel had previously been discovered by a Frenchman named Bernard Palissy. Even more famous than Palissy ware, or indeed than any pottery of any period, is the highly decorative Henri Deux ware, sometimes called Oirin ware. Much of the value of this pottery is no doubt due to the fact that very little of it was made. Naturally at the present date examples of it are exceedingly scarce, in fact only sixty-five pieces are known to exist. In 1882 a small cup was sold for the enormous sum of £1218, while two years later a candlestick, about twelve inches high, fetched £3675!

England can boast of no ancient history in pottery-making. Until quite recently the only ware produced in this country was coarse and clumsy, and the refined rich were obliged to send to Holland for their china. It was not until the eighteenth century that any decisive improvements were made. In 1730 Josiah Wedgwood was born. His father was a potter, and Josiah was set to work at the same trade at the age of ten. From the first Josiah was filled with the possibilities of pottery, and was inspired by an ardent desire to elevate and beautify his work. His first efforts were directed towards improving his materials, and in 1763 he patented a process for making a beautiful porcelain of a creamy-white tint. This became known as Queen's ware, in honour of

Queen Charlotte, who greatly admired the ware and encouraged Wedgwood to further efforts. But Josiah realized that the production of beautiful material was not the limit of his ambition. He recognized that a graceful decoration was just as essential, and he now set himself to study the beautiful forms and designs of ancient artists. Not content with this he employed R. A. Flaxman, a sculptor who attained a high reputation in the eighteenth and early nineteenth centuries, to provide designs for the celebrated Wedgwood ware.

We cannot be too grateful to Wedgwood for the artistic treasures he has left us, and incidentally he greatly improved the condition of the inhabitants of the potteries. It was largely due to his influence that the Grand Trunk Canal was cut, by which the Potteries were put into communication with the outer world; but that clearly is another story. Josiah became a very wealthy man, and used his money wisely and benevolently. His works originally were at Burslem; but in 1769 he built a new factory at some little distance from the town. To this spot he gave the name of Etruria, in honour of the beautiful pottery of the ancient Etruscans. In the British Museum you may see the famous Portland vase—an ancient Roman vessel of dark-blue glass with a design in opaque white enamel. Josiah made fifty copies of this and sold them for 25 guineas each. If you wanted to buy one of these copies nowadays you would be asked to pay £200 for it, possibly more.

It is possible to knead the roughest clay into a practical vessel, but for the china and pottery of civilized

peoples something more refined is required. We are accustomed to think of pottery and porcelain as two distinct substances. Most people apply the name pottery to a thick kind of china, and porcelain to the thin kind of which, for instance, the best tea-things are made. As a matter of fact it is now very hard to make any distinction between the two, and the reason for this is so interesting that I will tell you the story in full.

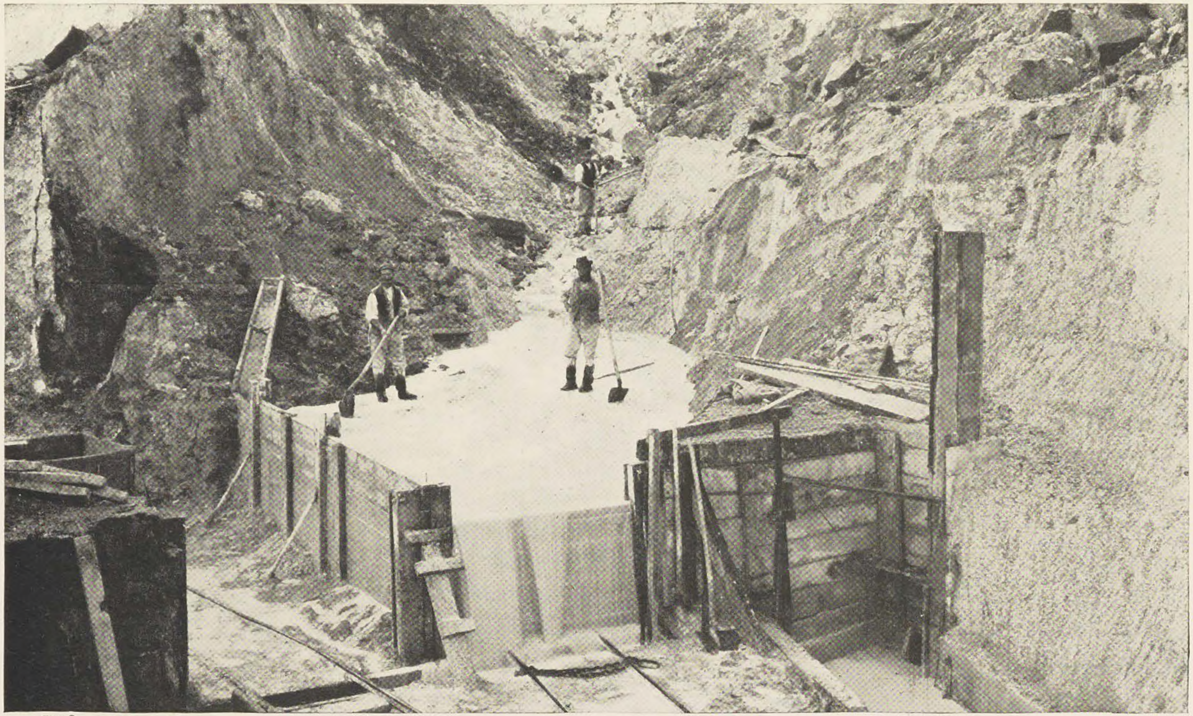
We must go back a long way to find the beginning, and, as usually is the case with every great progressive step, the Christian religion provided the impulse. Civilization has followed close upon Christianity ever since the first Christmas Day. As I have told you already, the Chinese were the first exponents of the porcelain industry. But the Chinese were heathens. If they had been Christians we might never have learned their secrets, for we have to thank a missionary for our knowledge of their methods. In the beginning of the eighteenth century there was working in China a devout and ardent Jesuit missionary named Père d'Entrecolles. We may be sure that his labours were extremely heavy and the results often disheartening, but apart from his spiritual gifts he possessed a sound discernment in worldly matters. This is displayed in his letters home, and, fortunately for posterity, one of the things he thought worthy of describing in detail was the Chinese porcelain industry. Notwithstanding the secrecy with which this industry was carried on, Père d'Entrecolles managed to glean a very clear idea of the processes. In his letters he laid particular stress on the necessity for

pure materials, saying that a single fine hair or a grain of sand left in the clay might entirely spoil a piece of work. He also observed that the best clay was only found in certain districts, and that in those districts the best work was produced. He was able to convert many of the potters, and these humble disciples came to him for help in a very curious problem.

No piece of Chinese porcelain was the work of one man. It passed through many pairs of hands before it was completed, sometimes as many as sixty or seventy. Now it is easy to see that new patterns were almost impossible. When Ching was making the base, and Chang was making the body, and Hi-Hi was making one handle, and Ho-Ho was making the other, to say nothing of the various persons engaged in making the neck and the tip, it is obvious that they all must be working to the same pattern. So long as they were producing the ordinary work of the factory this standardized-piece-making answered very well. There was a certain sameness of design, but the buyers did not seem to mind that. The trouble arose when the Emperor, wishing to send a graceful present to each of his neighbouring sovereigns, ordered the factory to make a number of articles of his own design. Ching, Chang, Hi-Hi, Ho-Ho, & Co. at once set to work on their various bits; but to the Emperor's disgust and their own consternation, the finished product was a scrappy, badly-fitting affair, inartistic and useless. Of course, the bastinado followed; and the unfortunate workmen at last begged Père d'Entrecolles to persuade the Emperor to cancel his order.

Père d'Entrecolles also sent home a detailed account of the firing and glazing of the china, the precautions to be taken to prevent hardening, the necessity for keeping the pieces separate in the ovens, and so on. He also revealed a very remarkable piece of trickery practised by the Chinese. Even in those days, it appeared, antiquities had a high value. The Chinese, knowing this, would make very careful and true copies of ancient pottery. They would then choose a particularly unclean and objectionable piece of ground, in which they would bury their copy for five or six weeks. When they dug it up again it would have all the appearance of a "genuine antique", and as such could be sold for a large sum.

These letters of Père d'Entrecolles fell into the hands of a Quaker of Plymouth named Cookworthy. He was an apothecary by trade, but after reading the letters he became fired with the idea of finding fine clay for porcelain in this country. He eventually succeeded, and found what he was looking for in Cornwall. He did not, however, keep his discovery to himself, but sold his patent rights to a man named Champion, of Bristol. The Staffordshire potters were quick to seize upon the new material and vigorously opposed the renewal of Champion's patent. A long struggle followed, the view of the potters as put forward by Wedgwood being that the natural products of the country ought to be free to all. Champion retorted that the potters could have the clay so long as they continued to make only earthenware and not porcelain, and this view was supported ultimately by Parliament. Now we see, as we always



CHINA-CLAY WORKS NEAR PERCORLA, ST. AUSTELL, CORNWALL

So fine is the china clay found in this district that it is exported to nearly all the countries where porcelain is made. This deposit was discovered by William Cookworthy in 1757.

shall if we wait patiently, the silver lining to the cloud. The potters were not going to be "done", and they proceeded to make earthenware, but earthenware of such wonderful beauty and delicacy that it rivalled and even outshone Champion's porcelain.

The finest china clay in England—and it is so fine that it is exported to nearly all the countries where porcelain is made—is found at Carclage, near St. Austell. It was this deposit that William Cookworthy discovered in 1757. Practically the same methods are followed in every case. The clay, after being dug from the mine or quarry, is taken to a mill in which it is ground and mixed with water until it is of the consistency of rather thin cream. In another mill, other substances are being ground to powder and mixed with water to a similar consistency. These substances vary in the different factories, but the object of all of them is to give firmness to the clay. Thus in England are used Cornish granite, calcined bones, and ground flints; at Sèvres, white sand and chalk; at Dresden, felspar and broken biscuit-porcelain. The essential point is that the resulting powder must be absolutely fine.

When the two mills have done their work the two fluids are mixed in a tank and the sediment is allowed to settle. The superfluous water is then drawn off and the sediment is further dried by evaporation, or by a pneumatic exhausting apparatus. Now it appears as a kind of tough dough and is all ready for the potter.

What a whirring and a whistling! What a queer smell! This is a workshop of one of the magicians

of modern times. They are not all dead and gone. Oh dear me, no! There are legions of enchanters, alchemists and necromancers, to be found to-day in London, Birmingham, Glasgow—anywhere. This particular magician is making dinner plates out of slabs of tough dough. He has a number of semi-free prisoners working for him, dying for him. What a lot of sickly men! What a lot of weedy, unhealthy women! If we follow them to their homes we shall find a lot of sickly children; and in the cemeteries scores upon scores of graves, some big, some tiny, but few of them the graves of old persons. People don't grow old who work in the potteries: they die instead.

But what a wonderful place it is, this room of whirring wheels! How deftly and quickly the potter forms his plate with an instrument called a guidepost, which cuts the clay to the exact shape and size. This is cut-and-dried work. I expect we shall like the tea-cups better. Here they are. See, there is nothing easier in the world. The potter takes a little lump of clay, puts it on his rapidly-turning wheels, pats and moulds it with his hands into the outside shape of a tea-cup. Now he turns it over, puts in his fingers, and hey presto! he has hollowed out the inside of the tea-cup. Now he has a whole row of tea-cups, and they are taken away to the drying stove. This toughens the clay, and when the cups come out they can be handled more freely and a finish given to their shape. Fine ornamental articles are sometimes made in plaster-of-Paris moulds, into which the clay is poured when in a liquid state. In other cases the

two methods are employed, the object being shaped in a mould and finished off on the wheel.

The next stage in the process is the first firing. This is carried out in what is known as the biscuit oven. The greatest care has to be employed to prevent the articles from touching one another in the biscuit oven, as if they did so they would harden and stick together. A number of pieces of burnt clay of very curious shapes are used to separate the articles as they are packed into the "seggars". Seggars are vessels made of a coarse kind of earthenware, and they are so shaped that numbers of them can be piled one above the other in the kiln, a pile of seggars being known as a "bung". Each kiln has, as a rule, eight furnaces; and each furnace heats six bungs. When every seggar is in place the furnaces are lighted. Only the best coal is used, as the smoke of inferior kinds might injure the china. Forty hours or a little more is the time usually allowed for baking in the biscuit oven, and when the kiln has cooled gradually the seggars are taken out and removed to the workshop to be unpacked.

If the articles are of what is commonly called stoneware, such as drain-pipes and hot-water bottles, they are glazed in the biscuit oven. Salt is thrown into the oven just when its highest temperature is reached. The sodium in the salt combines with the silica in the heated clay, and a soda-glass spreads over all the surfaces which the vapour can reach. If you examine a piece of stoneware—you are sure to be able to lay hands on a jam jar—you will see that the bottom is unglazed. That is because it was standing on the

floor of the seggar and the vapour could not act upon it.

Pottery that is not stoneware is known as biscuit-ware when it comes out of the biscuit oven, and is now ready to be decorated. Common pottery is coloured by means of transfer-paper, but finer kinds are painted by hand. After the printing or painting it is fired again to fix the colour, after which it is glazed by being dipped into a vessel containing a mixture called glaze, compounded in various ways. The biscuit-ware being porous, it rapidly absorbs the glaze and is now ready for its third and last firing. In this oven the glaze melts and solidifies again as a hard transparent surface through which the design shows brightly. In the case of fine porcelain, which, of course, is made with much greater care and attention than ordinary crockery, the colours and gilding are applied on to the glaze, not on to the ware. Porcelain objects of great value are not baked by the hundred in kilns, but separately, in what are known as "muffle" furnaces; that is to say, in small ovens served by one furnace, the heat of which envelops the oven in a jacket.

While we are talking about glaze I will tell you the story of Bernard Palissy, whom I have mentioned before. His life is a record of poverty, contempt, discouragement, and imprisonment, with a few years of fame and royal patronage, but he more than achieved his object, as we shall see. Born in 1509, Palissy first followed the trade of a glass-painter, varied by portrait-painting when he could find any sitters who could pay. In pursuit of this occupation he wandered

nearly all over France, but at last he married and settled down at Saintes as a land-surveyor. In those days only the roughest earthenware was commonly used in France, and Palissy had no prescience of his future lifework until one day when he chanced to see an enamelled cup of Italian workmanship. We can imagine the delight of his artistic soul at the sight of a beautiful object, and from that time forward he devoted himself to the discovery of a similar enamel. The next sixteen years of his life must have been one long agony, short periods of intense hope being followed by the blackest despair. He had so little to start upon! Practically every substance he could find he pounded up in the hope of hitting upon the right one. Bit by bit he broke up all the household crockery to bake again in his furnace with additions of his own. Needless to say his little stock of money soon vanished, and then his experiments would have to cease for a time while he prosecuted his land-surveying. Then when he again had a small sum in pocket, he would shut himself up with his pots and his chemicals, only to realize another disappointment. Can we wonder that his wife "nagged" at him when, the crockery all smashed and the children crying for food, he still ignored them and went on with his seemingly-useless labours? But worse was to come. One day Palissy's hopes were realized. One single pot came out of the furnace covered with a pure-white enamel. All his ardour and his enthusiasm returned. Feverishly he built himself a new furnace, baked more pots, covered them with his compound and put them back for a second baking.

But, alas! the enamel would not melt. For a week he laboured and kept up his fire, then, his pots over-baked and his fuel all used up, he was obliged to give in. He was not the man to admit defeat, however, and we next see him borrowing money for more pots and more fuel. When that was gone he burnt the furniture, the garden fences, the flooring, anything; and while Madame Palissy runs down the street screaming that her husband is mad we see Palissy gazing with rapture on a rough pot covered with a shining white glaze. His enamel had melted at last. The year 1557 saw him famous, for apart from his glaze the design and colouring of his ware were beautiful and distinctive. But he was a man born to trouble, and 1562 saw him in the prison at Bordeaux on account of his Protestant principles. He was, however, speedily released, and was appointed "inventor of rustic figulines" to the king. For the next twenty years he lived an honoured life. In addition to his artistic work he gave lectures on natural history and physics, and is remembered as one of the first Frenchmen to advance sound theories on scientific subjects. In 1585 he was again thrown into prison as a Huguenot, this time in the Bastille, where he died in 1589.

Where should we be without glass? Think of the strides of science in recent years. Do you know what it is that has made them possible? Do you know that they might have taken place hundreds of years sooner if men had been more reasonable or less superstitious? Have you ever heard of the "Great Work" of Roger Bacon, Franciscan monk

of Ilchester in the thirteenth century? In it he suggests the use of lenses made of crystal to make "an instrument useful to old men, and to those whose sight is weakened, for by means of it they would be able to see letters, however small they are, made large and clear". The Pope, Clement IV, to whom the "Great Work" was presented, decided that no man could think such thoughts without supernatural assistance, and Roger accordingly was sent to prison. It is curious to notice that in olden days inspirations of a scientific nature invariably were considered to originate in realms of darkness. A desire to massacre one's enemies, on the other hand, was taken as a divine command. The Pope ordered the "Great Work" to be destroyed, but not before one man had peeped into it. This man—Salvino degli Armati was his name—produced a pair of magic glasses four years later. This was, of course, the first pair of spectacles. The "Great Work" was hidden away by Bacon's friends to prevent its destruction, and was not rediscovered until 1733. We should like to give the credit of the first microscope to an Englishman, but I am afraid there is no reliable authority for the tale of Leonard Digges, who is reputed to have read the "Great Work", in the sixteenth century and to have made an efficient instrument by placing one lens behind another in a tube, in accordance with Bacon's theory. I do not know how he found the "Great Work", nor why, if he found it, nobody else did; but if we dismiss Leonard Digges we must believe in a Dutchman, Zacharias Jansen.

I am afraid I have wandered away from my subject.

I was asking you, was I not, where we should be without glass? You have probably replied, or would have done if I had given you time: "Don't know"; and, to tell the truth, neither do I. We may be quite sure, however, that without the telescope we should know nothing of the more distant stars. That might not make very much difference to the ordinary individual perhaps, except that where there is no knowledge there is ignorance, where there is ignorance there is superstition, and where there is superstition there are cruelty and sorrow. But without the microscope we should be, practically, still in the Middle Ages. The science of biology, our knowledge of the properties of metals, the doctor's knowledge of germs and bacteria, and a considerable proportion of the manufacturing industries of to-day would not exist. The naturalist would be a person who knew the names and habits of the members of the animal kingdom, but few other people would know anything about their appearance, because there would be no photographs. The devoted observer, the most rapid sketcher in the world, finds himself defeated by the alert senses and lightning movements of a bird or winged insect. The naturalist may spend hours waiting and watching in dead silence till his prey comes within range of observation; but in an instant it will be off again, scared by the rustle of the leaves as the naturalist brings out his pencil perhaps, or some equally slight sound. The camera, however, records in the act of startling. The click of the shutter comes after the picture has been taken. Again, the most intrepid artist can do scant justice to his

work when surrounded by savage beasts. The kinematographer is in better case, and recently a film was taken of a lion in full charge. The operator stuck to his post until the lion was *only 15 feet away*. And what should we know of the wonderful science of botany without the microscope? A primrose by the river's brink would be little more than a yellow primrose to anybody. At any rate, we should know nothing of the marvellous structure of plants. Your mother, I dare say, likes to have flowers on her table and flowers to wear all the year round; but she could not have them if the gardener had no frames or hothouses. It is more than likely, moreover, that without glasshouses we could not keep any specimens of exotic vegetation in this country. Unless we were able to go abroad and see them for ourselves, we should never see the orchids of South America, the Victoria *Regia* of the Amazon, or the bamboos of India. You see, I am giving no consideration to the artistic uses of glass. I am only hinting at a few of its practical applications.

How, then, was discovered this wonderful substance that has revolutionized the ideas of scientists on almost every subject, that has shown doctors the way to stamp out deadly diseases, and that can bring the Antipodes into a London music hall? Many nations claim the honour of the discovery, and, as a matter of fact, it was such a simple business that it is likely it was discovered not once, but many times—at different periods by different peoples. One story commonly accepted is probably only a repetition of the others. This story is told by Pliny, but, with all due respect, we

must remark that his tale is a little bit "tall". Certainly he himself begins the account with "fama est", so perhaps he had doubts of his own. However, the discovery probably was made in some such accidental way, so we will agree to accept Pliny's story.

Some Phœnician merchants were returning home after a voyage, bringing with them a cargo of natron. Natron is a mineral alkali, the substance which, in the Authorized Version of the Bible, is translated "nitre", and in the Revised "lye". The sailors were harassed by such violent storms that they were compelled to land on a sandy shore near Mount Carmel. Here they lighted a fire, which is always the first thing to do when one is shipwrecked, and proceeded to cook their dinner. In order to make a nice steady little stove to hold their pots, they fetched some blocks of natron from the ship and put them round the fire. In due time the natron got hot, melted and mixed with the sand, forming a layer of glass. As I have hinted, we are not obliged to believe this story, but we know for a certainty that sand brought down from Mount Carmel by the River Belus was for a long time used in the famous glass manufacture of Sidon. The Egyptians, however, made glass for many centuries before the Phœnicians ever thought of doing so, and we may take it as established that the Egyptians discovered the art and the Phœnicians learnt it or stole it from them. The Egyptians understood glass-making as early as 3300 B.C., though there are no specimens of such antiquity now in existence. The oldest glass which has been discovered bears the name of Queen Hatasu (1700 B.C.). Vases of this

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SOME EXAMPLES OF "WHITEFRIARS" GLASSWARE

From the works of Messrs. Parells, at Whitefriars, London. The jug is mounted with silver and pearl, the vase with silver and enamel, and the inkstand with silver.

date are of opaque blue glass ornamented with wavy lines in white or bright colours. They also made imitations of precious or ornamental stones, such as emeralds, jasper, and onyx. The first transparent glass appeared in the twenty-sixth dynasty (660 B.C.). Glass-making has never become extinct in Egypt, and attained a high degree of art and beauty in the Middle Ages. From Egypt and Phœnicia the industry spread to Europe and Assyria. The Romans practised it with great success, and their cameo vases are of priceless value to-day. I have already spoken of the Portland vase to be seen in the British Museum. This is a cameo vase, and is larger than the one in the Naples Museum found at Pompeii. Even fragments of these cameo vases are valuable, and are carefully preserved in various museums. Our own treasure, the Portland vase, was once smashed by a maniac, but it has been most wonderfully joined together again.

With the fall of the Roman Empire the glass industry declined, to rise again and flourish in Constantinople. Here it received a Byzantine influence, and Byzantine glass mosaics are specially famous. Here the Arabs learnt the art, and Damascus glass became famous. Here also the Venetians received their first lessons. The Venetians began to make glass in the seventh century, but so closely did they guard their secrets that no other countries were able to compete with them until the sixteenth century, although a rough glass was made in Normandy in 1294. Some of the most beautiful stained glass in the world is to be found in French churches, dating from the twelfth

and thirteenth centuries. Most of our old stained-glass windows suffered destruction in one or other of the religious upheavals which have shaken the country, but the windows in the choir aisles of Canterbury Cathedral are believed to be twelfth-century work; while York Minster, some of the Oxford chapels, and Gloucester Cathedral possess much lovely work of later date.

A glassworks is a fearsome place to visit. It is the abode of terrific heats, of angry hissings and bubblings, of tanks full of white-hot metal capable of destroying hundreds of lives, of lurid flames and blinding lights. The workmen handle the molten glass with the contempt born of familiarity; but we can imagine that the most hardened of them was once a timid beginner. Of course every precaution against accidents is taken, and many of the operations are now performed by machinery. The finest work, however, is still produced by a man with primitive tools. We can make machines which will turn out bottles by the thousand, and very good bottles too; but the human hand is necessary to evolve a beautiful decanter from a shapeless mass of molten glass.

The first thing the glass-maker does is to provide himself with pure materials. The bare essentials of glass-making are, according to one process, sand, carbonate of lime, and carbonate of soda. The best glass, however, is not made simply by the fusion of three ingredients. The sand must be of exactly the right kind, and the British glass-maker has to send abroad for it. Fontainebleau gives us the best sand for the purpose, and there are deposits of excellent sand at

Lippe, in Germany. Useful sand is found in Belgium, but it is tainted with iron and aluminium. In England there are deposits at Leighton in Bedfordshire, and Lynn in Norfolk. The intrusion of foreign substances in the sand does not, of course, matter much in the manufacture of cheap or common glass. As you have read already in the chapter on salt, our alkali works are of great value to many manufactures. Amongst others the glassmaker is a large user of alkalis, such as carbonate of soda, sulphate of soda, potash, and lime. Besides these, other substances which he may use are baryta, lead, carbon, and cullet. Cullet is broken glass of the kind it is intended to make. These raw materials are put in their proper proportions into vessels known as glass-pots, made of Stourbridge fireclay most carefully prepared and glazed. In England these pots are made entirely by hand, but on the Continent they are shaped in wooden moulds. The clay takes many days to prepare, and when it is ready for use the building of the pot is a lengthy process. The workman has the clay made up into little rolls, and he builds the pot by adding two or three inches to its height every day. When it is completed it is put away for three or four months, after which it is annealed by being made red hot and kept red hot for several days. At the same time it is glazed. Different shapes are used for making different kinds of glass. For instance, window glass is made in an open pot like a flower pot, and flint glass is made in a pot like a fowls' drinking trough, without the trough.

Well, we have made our pot and chosen our ma-

terials; the next thing to do is to make something. Needless to say we are ambitious; so we may as well start at the top of the ladder and make optical glass. This is one of the most difficult and delicate branches of the glassmaker's craft, and one which has to be performed by skilled labourers. We can trust no machines. We will make it ourselves.

Have you the pot? Well, stick it in the furnace. I will smoke a cigarette, and you can read a book until the pot is red hot. We shall have a good deal of waiting about to do one way and another. When it is red hot and glowing dully we drop our ingredients in, very gently and gradually. All in? Then let us go to sleep for ten hours. At the end of ten hours we attend to the furnace, for it now has to burn its hottest for twenty hours. The next process is most exhausting, but as we are only pretending, we can easily manage it by ourselves. The real workmen, poor things, perform this stage in short shifts, but you and I are quite equal to it, or anything else—on paper. Now we dress ourselves up in asbestos suits—we are going to be just a little hot, you know—and we will take it turn about to work the handle. What handle? Oh, the handle that turns the fireclay rod that stirs the glass that boils in the furnace. A mere nothing. We only have to keep doing it for fifteen hours. It is certainly warm work—hotter than the hottest day; hotter than the kitchen fire when your cook is getting ready for a party; hotter than it was on the engine when that jolly engine-driver let you step up to look at the fire —(what ages ago that ride seems to us now!)—hotter

than the stokehold of the steamer that took you down the coast; hotter than anything we ever have known. But we must not stop stirring. Fortunately the furnace is cooling all the time, but the cooler it gets the stiffer grows the mixture, and the harder it is to stir. But everything comes to an end, and at last we can stop stirring and leave the furnace to cool for five hours longer. Then we go and seal it all up with bricks and fireclay, and leave our glass to anneal. You may now sleep for a fortnight if you like. I am going for a sea voyage to recuperate.

At the end of a fortnight we return to our furnace and carefully take out the pot. Don't worry, they are generally cracked. It is easier to break away, and we shall not have to use the hammer so much. But alas and alas! Where is the beautiful solid lump of glass we expected to find—well, no; perhaps hardly expected, but certainly hoped? Our glass has cooled itself into a mass of fragments. Never mind, the clearest of them will be used as lenses; and after all, we ought not to have dreamt of doing "first go" what is rarely achieved by experienced workmen. For years the highest glassmakers of a famous French factory have been engaged in attempting to cast a glass for a gigantic telescope at the Mount Wilson observatory. Scientists from far and near have gathered at the factory offering help and suggestions, but without success. The disc is required to measure 100 inches in diameter and is calculated to weigh $4\frac{1}{2}$ tons.

The machinery in use for moulding and making articles of common utility, such as bottles, tumblers,

lamp glasses, &c., is very ingenious and complicated, but the processes are hardly so interesting as those performed by the workman himself. In the making of plate glass the only figure which appeals to us is that of the ladler, who, enveloped in thick felt, a mask over his face with green-glass spectacles, has to guide nice little ladles, which at one scoop lift 200 pounds of seething incandescent glass. The ladler causes the ladle to dip into the tank and then jerks it up again, breaking off the threads of glass which adhere to it. He hooks the handle of the ladle on to an overhead trolley, and by exerting all his strength he raises the filled ladle from the tank and sets it on its journey to the casting table. Here the ladle empties itself, and the liquid, which, being cooler, is now beginning to set, is flattened out into a red-hot sheet by a huge iron roller. It is left on the table until it has cooled sufficiently to be lifted and moved, when it is placed upon a stone slab. The slab travels through a long tunnel, hot at first but gradually growing cold, and when it emerges at the other end the glass is annealed and ready for cutting. There are wonderful machines for polishing the huge sheets of plate glass that one sees, for instance, in the windows of big shops.

The making of sheet glass is a much more personal affair, and the quality of the glass depends largely upon the skill and care of the workmen. There are three different stages in the process, performed by three different operators — the pipe-warmer, the gatherer, and the blower. The pipe-warmer's job seems fairly simple to the uninitiated, for he only has to warm the blowing-pipe. This is an iron pipe

between 4 and 5 feet in length, having a mouthpiece at one end and widening into a cone at the other. When it has reached the right temperature the warmer blows through it to see that it is all clear, and then hands it over to the gatherer. The gatherer is a very important person. Unless he gathers properly the glass is faulty. Only a very good gatherer is employed for the finest glassmaking, and yet, as with the pipe-warmer, his work appears easy at first sight. He begins by dipping the pipe into the tank and twisting it slowly until he has collected some glass upon it. You imitate him in a homely way every time you help yourself to treacle. When he has gathered as much as he can manage, he lifts up the pipe and allows the glass to cool. Then he dips and twists again, and it is here that his skill displays itself, for he must not allow air-bubbles to collect between the layers, and he must be careful to keep the gathering regular in shape. When he has finished, the blowpipe has a round mass of glass on the cone, something like a flattened bottle in shape, with its neck fitting round the nose of the pipe. Then the blower takes charge, and seats himself on a little platform facing the furnace, with a pit below him. He heats the bulb of glass and then swings the pipe backwards and forwards in the pit, blowing through the pipe from time to time. By heating, swinging, and blowing alternately the globe of glass is extended to a tube. Then a thread of red-hot glass is twisted round the end of the tube for a few moments, and when it is removed the glass can be cut with cold shears. Now the tube is allowed to cool. It is next

cut open with a diamond and flattened out on a slab, which, as in the case of plate-glass, sets out on a journey through the annealing tunnel. Of course, cheap sheet-glass is made by machinery nowadays, but it is poor stuff compared with the product of the warmer, the gatherer, and the blower.

We may talk of the "primitive tools" still in use in our glass factories, but we must not try to disguise the fact that good glass is a recent invention. The first clear-glass mirror was made about the middle of the sixteenth century and was a luxury for a queen. If you ever have been to Holyrood Palace you will have tried to look at yourself in the mirror of Mary, Queen of Scots—the first glass mirror in Scotland—and you will not have felt flattered by your reflection. The artistic glassware of the ancients is wonderful, but the beauty of their vases is largely due to bubbles and veins in the glass which now would be considered faults. You know, perhaps, that nowadays stained glass is attaining an artistic value which it has lacked for some hundreds of years, but you will hardly guess the reason. It is simply that the manufacturers have been clever enough to try to make bad glass! The jewel-like appearance of ancient stained glass is due to the bubbles and imperfections of the glass, which break up and deflect the light.

Finally, it is curious to note that in the beginning of the seventeenth century Sir William Slingsby, Sir Jerome Bowes, and Sir Robert Mansel were greatly interested in the new fuel known as coal. They were also interested in glassmaking. They therefore chose the surest way of advancing both industries by start-

ing a glassworks which should burn coal instead of wood. The use of a new fuel, however, introduced new difficulties into the processes, and a series of experiments followed which resulted in the greatest achievement of any glassworker. This was the making of flint-glass, the clearness and brilliance of which surpassed anything that had been made before. The Bohemian glassmakers who had previously produced much of the world's clear glass gave up in despair, and turned their attentions entirely to coloured work. The English flint-glass provided Newton with the prism by which he originated the science of Spectroscopy, and furnished scientists with lenses for their microscopes and telescopes.

CHAPTER VII

The Craft of the Quarryman

FROM time immemorial, men have built their dwellings of substances obtained from the earth. The mud hut was, no doubt, a very, very early product of man's ingenuity. The idea was probably not his own, for we may consider it very likely that he copied and improved upon the house of the beaver; but it was the first of his homes to have any lasting qualities. Durability was the aim of the ancient builder. When we look at any architectural relic of the past the first thing that strikes us is the amount of material used—the immense thickness of the walls —the tremendous blocks of stone employed, and the mighty beams, one of which would be sufficient, so we may suppose, to hold up a whole row of modern villas. The next point which puzzles us is: How did they do it? How did those half-civilized people, with no steam or electricity to work for them, few and clumsy appliances, and but a rudimentary knowledge of mechanical and physical laws, manipulate the materials and place these tremendous weights in position? The answer is, probably, by infinite labour and patience. That they were unsparing of their energy is proved by the wonderful ornamental work

they achieved, not only where it was to be seen, but in places where it would not be seen, save by the eye of the God for whom they worked. The building of a house in the early Middle Ages, when the builders' craft first came into prominence in Europe, was a thing, not of a year, not of twenty years, not of a lifetime even, but of several generations. A man would hew his timbers, collect his stone, or more probably his mud, build the framework of his house, and then move in. Then the rest of his life and his sons' and his sons' sons would be spent in beautifying the interior with wood- and plaster-work, and, as the family increased, adding to the structure room by room. In those days there were no Sanitary Inspectors, Urban District Councils, or Boards of Works. A man could build his house as he liked and leave a lasting monument to himself, always provided his enemy did not burn it down, or a conquering army destroy it. Houses built of "wattle and daub", as it is called, are still to be seen standing in remote parts of the country.

Men built houses for themselves in their spare time as a luxury. What a different form of labour was that bestowed on the churches and cathedrals by men who lived only to glorify their God and their religion! It was in the early days of Christianity, when religious fervour burnt clear and bright in men's breasts, that the Guild of Masons had its origin. Masons, after serving their apprenticeship and learning their trade, were obliged to travel about to find work. Wherever a church or cathedral was being built, there the masons congregated. Now, it

is easy to understand that the wardens whose duty it was to supervise the masons would not accept men without good credentials, yet in those days few people could read or write. The apprentice, therefore, on becoming a fully-fledged mason, was made acquainted with certain words and signs, the knowledge of which proved him to be a good craftsman. It must be remembered that these masons worked according to directions—at least to a certain extent—the building being designed, probably, by an abbot. The masons themselves were not architects, as is frequently stated. In later times, in Germany, it happened in more than one instance that a church was designed by a mason, but in no case is the completed work comparable with the early French edifices.

The French, however, did not attain perfection in a day. The first attempts of the Normans were far from being successful; in fact, it is said that their towers often fell down from sheer inability to stand up. The beauty of their best work is still visible in many an English church, although they embodied many Saxon features in their buildings in this country. An example of the pure Norman style may be seen in St. John's chapel, Tower of London, which was built by William the Conqueror. On the whole the masonry work of the early Middle Ages was very bad, the stones being rough and unhewn and irregularly coursed. The Egyptians have shown us how wonderful masonry work can be. They used no mortar in the building of the pyramids, every one of the huge blocks of which they are composed being polished and fitted into its neighbour by an accurately

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IN A NORTH WALES QUARRY

Quarryman suspended by a rope on the rock, throwing down blocks loosened after blasting.

cut joint. The Romans used three kinds of masonry which greatly resembled those in use at the present time, namely, rubble work, coursed work, and Ashlar. In rubble work the stones are coursed—that is to say, laid down—irregularly, no pains being taken to match them in size or shape. Coursed work, on the other hand, represents a regular and level system of laying down the blocks. Ashlar is an improved and perfected kind of coursed work.

We must remember that for all the beautiful examples of masonry work that remain in our churches a great many more have vanished. In some cases natural causes have been at work—the climate has worked havoc, or the stone has been of an unsuitable quality—but in other cases man himself has been the destroyer. When Henry VIII dissolved the monasteries much damage was done and much beautiful work destroyed, for although monasteries began as simple and austere buildings they had arrived, in the sixteenth century, at being as richly decorated as any church. But Cromwell's soldiers caused still greater ruin, and by their wanton actions have left a blot on the fame of a great and good man.

The commonest kinds of stone used in building are limestones and sandstones. It is not unusual to hear building stone spoken of as freestone, that is to say, it can be easily—freely—worked with masons' tools. These two stones belong to the class known as sedimentary rocks. You will remember that the first rocks, those we call primary rocks, were formed by the cooling and consequent solidifying of molten minerals. Then epigene action, you remember,

broke up these rocks, and the fine particles were carried away by rivers and winds. The primary rocks that covered the surface in Archæan times were disintegrated and redeposited as secondary rocks. Thus, an igneous rock of Archæan formation reappeared in the Devonian period as a secondary rock. Now sandstone is found in great abundance in many parts of England; and the same system extends over the greater part of Central Europe, so we know that a sea must have existed there at some time. Occasionally the waters would recede, leaving bare the masses of partially-formed sandstone. And we can imagine what strange creatures would straddle and sprawl about on the new hunting ground, leaving footprints and bones to tell us the story of their existence ages afterwards.

The scientific definition of sandstone is that it is a rock composed of compacted indurated sand, the sand itself, of course, being grains of quartz. According as the grains are large or small the rock is called coarse- or fine-grained sandstone. It lends itself very well to dressing, and is well adapted for present building purposes, but that it does not endure for ever is proved by the sad decay of Chester and Durham cathedrals; and of Holyrood, Melrose and Jedburgh abbies, and other Scottish antiquities. Of course the stone varies in quality, that from some quarries being much more durable than that from others. Expense is frequently an obstacle to using the best stone, that nearest at hand being generally used.

Limestone is a rock composed wholly or principally of carbonate of lime, a substance which is one of the

most widely distributed in nature. William Black, in one of his novels, refers scathingly to the English Channel as "diluted chalk and water". Nevertheless, the existence of the great deposits of limestone is a perpetual object-lesson to those of us who grumble at our lowly places in the world. The lives and deaths of countless billions of creatures infinitely more humble than ourselves have contributed to the making of those cliffs

> " . . . that on our coasts
> From Deal to Dover span",

and all other limestone rocks. I referred to the eozoon in Chapter I, and you will remember that I there told you that geologists could not agree as to whether he was or was not responsible for building some of the rocks in the Laurentian Mountains, that immense range which traverses the states of Quebec and Ontario. We do not need to concern ourselves with the controversy beyond remarking that, if he really did exist, the eozoon was the earliest form of animal life. There are, however, many limestones which are indisputably nothing but the skeletons of marine animals. Some of the pyramids were built of nummulitic limestone. This is a stone composed entirely of nummulites or "money fossils", tiny creatures whose bodies and coin-shaped shells have fossilized into a hard rock: fresh evidence of the efforts of our friends Disintegration and Segregation! The nummulite in his lifetime absorbed lime from his drinking water and made a shell of it. He was a convivial soul, living among innumerable others of

his kind. He was not so very small, and sometimes equalled a two-shilling piece in diameter. Nor did he live so very long ago, comparatively speaking. His first appearance was made somewhat diffidently in the Carboniferous period, but he attained his heyday in Eocene times. Now we find beds of nummulitic limestone, often several thousand feet in thickness, extending from the coast of Spain across Europe to Egypt and Asia Minor, through Persia and the Himalayas, till we lose sight of it on the coasts of Japan.

These tiny organisms, that have helped so largely to make our present world, are so wonderful as to be worthy of ampler description. The great family Foraminifera, of which the nummulite is a member, is responsible for the building, in Europe alone, of all the chalk in southern England and northern France; the formation known as the "Paris basin"; a similar formation in Austria and Italy, and a large area in Russia! In each of the other continents they have left records of equal size. And yet we are told that many of the Forams are so minute that twenty of them could be easily accommodated in a little cup formed from a pin's head. Some of them attain quite a respectable size, however, for they are nearly as large as two pins' heads. The shells are made in a variety of beautiful shapes and forms. Some of them only contain one room; while others, the residences perhaps of the Foram aristocracy, contain many, arranged in one row or several. These rows are sometimes straight and sometimes formed in a spiral, but, as a rule, the first-made room is the smallest, each succeeding room being a little larger. Most of the houses

consist of several rooms, a fact which, in itself remarkable, becomes more remarkable still when we notice that the little inhabitant lives in all his rooms at once; that is to say, his body is continuous throughout the shell. We must respect the Foraminifera as being one of the most potent factors, not only of the existing world, but of the world of the future. They are always at work repairing and renewing our shores, which the ocean is constantly trying to wear away.

Whereas the composition of the shells of Foraminifera is carbonate of lime, their kinsmen, the Polycystins, have a flinty basis. The Polycystins make a shell even more beautiful than the Foraminifera. Their skeletons are of wonderful transparency and formed in one continuous piece. The Polycystins are pierced all over with tiny windows, convenient for projecting feelers; but some forms are not obliged to live all over the house at once, but can retire upstairs if need be. The Polycystins, though even more numerous than the Forams, are not nearly so widely distributed, and at one time it was believed that they were only found at Barbados. Recent investigation, however, has proved that they exist in many other parts of the world, but I am sorry to say there is no evidence of their presence in the British Isles. Any boy with a powerful microscope can hardly do better, I think, than invest in a slide of Polycystins, if he does not possess one already. The extraordinary beauty of the real specimens cannot adequately be shown by any illustration.

Still another of Nature's rock-builders is the Diatom. Like the Polycystin, the Diatom has a flinty founda-

tion, but this is practically the only point of resemblance between the two. Some of them are so minute that a hundred thousand of them would make a line less than 1 inch in length, yet a bed of fossil Diatoms, 15 feet deep, makes the site of the city of Richmond, Virginia. The Diatom may be found in almost any fresh water, whether of ditch, pond, or brook; whereas the Forams and Polycystins are purely marine creatures. The beauty of a Diatom lies not in the structure of its skeleton but in its markings and shape. Almost every form is represented, and each specimen is beautifully engraved with a pattern all its own. Diatomaceous earth may be found in many parts of Great Britain; for instance, at Peterhead, Dolgelley, and Lough Mourne. Diatoms, be it remembered, are lowly plants: Foraminifera and Polycystins are amongst the lowest forms of marine animals.

There are two limestones in common use in this country. Dolomite or magnesian limestone is found in Permian formations extending from Nottingham to Tynemouth. Amongst the important buildings in which it had been used are the Houses of Parliament, but it is far from being well adapted to London smoke, and the structure is rapidly decaying. Oolitic limestone is found practically all across England from Dorsetshire to Yorkshire. The well-known quarries of Bath and Portland produce oolitic limestone, that of Portland having been used for St. Paul's Cathedral. A great part of Canterbury Cathedral is built of limestone from Caen. This stone is very beautiful and well adapted for working, but is not very durable.

Granite is an excellent substance for building pur-

poses in that it is durable and ornamental; but it is exceedingly hard and difficult to work. It is impossible to saw it in the usual way, and it has to be worked first with heavy hammers and afterwards with chisels. It is an igneous rock, and is made up of quartz, felspar, and mica; the felspar being responsible for the grey or red colour of the rock. Many other minerals are found in granite rocks, and sometimes some of the less precious stones, such as beryl, garnet, topaz, and tourmaline, occur. Aberdeen granite is grey in colour, the Peterhead being the reddish variety.

As I have said, granite is exceedingly hard to work; yet, knowing what we do of the art of the Egyptians, we can hardly be surprised that they knew of ways of dressing it, and could even engrave their hieroglyphics on it. The Rosetta Stone, which, as you are no doubt aware, furnished the clue to the reading of Egyptian hieroglyphics, was a slab of black basalt. We poor moderns can make no better use of basalt than to throw it on our roads to defy the attacks of time and traction engines, but the Egyptians could write on it so legibly that the characters could be discerned thousands of years afterwards.

Slate, though it is rarely used for walls of houses, is so important as a roofing material that it must be mentioned under this chapter heading. Slate is what is called an argillaceous rock; that is to say, it is of a clayey nature. The course of ages—slate dates from Palæozoic times—has changed the soft clay into a strong, hard substance, durable under practically all climatic conditions. It is always of a purplish-green tint, the only exception being the red slate found near

Quebec. When we laboriously worked sums and made eccentric pothooks on our slates at school, we thought little enough of the substance we were defacing. Yet no doubt that very slate came from the vast quarries at Bethesda, now a huge amphitheatre instead of a mountain, a circus in which the Colosseum of the Romans could be dropped and lost. Or perhaps it came from Llanberis, where a mountain has been converted into a grand stand from which one can view the lakes and mountains opposite. If you have ever spent a holiday touring in North Wales—almost any part north of the Cader Idris range—you cannot have failed to notice the great number of scarred mountain sides, huge gashes cut in such places that it looks almost as though man had deliberately set to work to spoil some of the most exquisitely beautiful glens in the world. Old lead and copper workings are often blots on the landscape, but lead and copper workings are generally to be found on bleak moorlands, rarely in the sheltered vales that are the chiefest glory of Wales. Slate quarries, unfortunately, are literally everywhere, because the predominant rock is slate. The pity is that the damage to the landscape having been done, there is no longer opportunity to work the quarries, except in a few specially favoured localities. For the most part they are old wounds that the mountains show, gaping still and incapable of being healed. The quarries are abandoned, cold, but always aggressive; and the hideous villages that once held the quarrymen are almost deserted. They are mean and squalid beyond words, these villages, with the squalor of desolation. There is good stone in the quarries

C 708

By kind permission of the Dinorwic Slate Quarries

THE DINORWIC SLATE QUARRIES IN NORTH WALES

This famous quarry consists of a series of galleries or flights of terraces cut one above another into the face of Eledir Mountain, and has the effect of some giant staircase. From the lowest gallery to the topmost the height is 1800 feet. Each gallery or terrace has a height of 75 feet, and it is from this face or wall of rock that the quarrymen blast and bring out the slate.

still, but nobody wants it. Not because slate has gone out of fashion—greater quantities are used every year—but because the builder finds it cheaper to get it in America, and pay freightage on it, than in Wales —an anomaly that I must leave you to puzzle out for yourself.

The big slate quarries are interesting places to visit, but their chief interest lies in the consummate skill of the men who split and dress the slates, rather than in the actual operations of quarrying. I shall not trouble you with a description, especially as the plate gives a good view of a typical quarry. The quarries have generally the terraced appearance shown in the photograph. The "steps" may be anything from 50 to 100 feet above one another, and the total depth of the quarry may be 1000 feet or more. There is thus an enormous face from which the stone may be got. Each terrace has its own system of railway tracks, the lines being so arranged that the full and empty trucks are properly balanced and never get in one another's way. Sometimes the trains are worked by locomotives, more often by gravity, the descent of the full trucks hauling up the empty ones. The trains are hitched on to ever-moving endless ropes running on "idlers" on just the same principle as that of the cable system of tram-way-working still surviving in a few towns. A big slate quarry is a noisy, dusty, nerve-racking place, and the prudent look on from a distance.

Not all slate quarries are open to the heavens. Sometimes valuable kinds of slate do not disclose themselves in an outcrop, but have to be searched

for and mined from considerable depths below the surface. This sort of quarry is, more properly speaking, a slate mine, and is approached by "drifts", that is, tunnels driven into the hillside. Not very long ago I was in a remote part of Wales, and I decided to explore the workings, in a neighbouring mountain, of a slate mine that had been abandoned for a long time. I started down the drift gaily enough, but I had not gone far before a terrific explosion, apparently deep down in the earth, nearly shook me to pieces. I was so much startled that I turned tail and fled back to daylight. It was an ignominious retreat, but a sudden explosion in a deserted mine does not help one to a dignified bearing. Afterwards I found that blasting operations on a large scale were being carried out on the other side of the mountain.

In this country we do not hear much of marble as a building stone. We have no sufficiently large quarries of suitable stone, and the cost of bringing it from Italy would be prohibitive to most persons. We think of marble chiefly as a material for monuments and statues. But in Italy, the land of quarries, marble buildings are as common as brick in London. This is due not only to the existence of the marble but also to the fact that the quarries of Carrara are close to the sea, and transport of the stone is thus simplified and cheapened. There are altogether, at Carrara and Massa, as many as 400 quarries, which produce more than £500,000 worth of stone yearly. This sum represents about 150,000 tons of stone, but it is grievous to think that, to produce that amount of saleable stone, about 500,000 tons of stone are

quarried, leaving a waste of 350,000 tons. The appliances used are so primitive and the blasting is carried out in so casual a fashion that often a large blast will result in nothing but useless chips. The marble is also greatly marred by the presence of grey veins; for, of course, the blocks are required to be a pure white. These quarries have been worked for over 2000 years, but fortunately they show no signs of becoming exhausted.

Marble is a crystalline limestone. It seems very wonderful, does it not? that this hard glossy substance is really only another form of the gritty, powdery chalk we know so well. If you tried to carve and shape a piece of chalk you would not have much success, for it would break and crumble under the knife. But a piece of marble will never crumble. How, then, has the chalk changed its nature? Remember, in marble it is the rarest thing to find any recognizable trace of marine life. Such an event has happened, however, and I know of a case in which a boy's alley-taw broke across, revealing a perfectly-preserved shell embedded in the centre. The marble of the Carrara quarries has been classed as an altered limestone of the Triassic period. Various natural processes have been at work all the world over performing these alterations, the most efficient being our old friend hypogene action. You remember that the eruptive rocks that have been formed by heat—such as granite, basalt, lava, porphyry, and others—were forced through the fissures in the earth's crust in a molten state. On their way up to the surface they naturally distributed some of their heat through the

adjacent strata, which could not help toasting to a greater or less degree. As toasted bread is crisper and browner than untoasted, so the toasted limestone hardened and shrank upon itself. In the same way coal was probably turned into anthracite or graphite, and sandstone into quartzite. The stone commonly known as Sussex marble is nothing more nor less than the remains of fresh-water snails—Paludinæ—held together by crystallized carbonate of lime. At Chichester, in 1723, a slab of this marble was discovered, bearing the following inscription in Latin:—

"The College or Company of Artificers, and they who preside over sacred rites, or hold offices there by the authority of King Cogidubnus, the legate of Tiberius Claudius Augustus in Britain, dedicated this Temple to Neptune and Minerva, for the welfare of the imperial family, Pudens, the son of Pudentinium, having given the site."

We cannot, with exactitude, call any British rock marble, because one of the essentials of marble is that it should be crystalline, and our so-called marbles are amorphous, that is, they are not crystalline in form. Our British marbles are simply limestones that are capable of taking a high polish. Many of them are very beautiful, such as those found in the Devonian system, in which corals are most wonderfully preserved. Other kinds, such as the Yeovil and Purbeck, are figured with shells. The most famous coloured marbles are the Rosso Antico, a dark red covered with tiny white spots; Verde Antico, a dull green; Giallo Antico, a yellow marked with black; and Nero Antico, a pure black.

Most of the ancient statues of the Greeks were executed in Parian marble, which is of a wonderful smooth whiteness. For a time marble from Mount Pentelicus enjoyed a vogue, but the statues that remain of that marble have not kept their finish and purity of colour in the same degree as those executed in Parian marble. The Parthenon at Athens, from which so many of the Elgin marbles were taken, is built of Pentelicus marble.

But blocks of marble, beautiful though they may be, are comparatively useless by themselves. It is the block of marble in the hand of a genius that is the miracle, the lasting memorial of man's art. Wonderful is the work of the painter, who, with a vision in his mind and colours at his hand, paints a beautiful picture; of the poet, who strings existing words, or the musician, who combines existing notes: but the creation of the sculptor, who, out of a block of unresponsive stone, fashions a lifelike figure or group of figures, is surely more wonderful still. If you are ever lucky enough to go to Paris, be sure to make a point of going to the Louvre and of standing before that wondrous relic of a bygone genius—the Winged Victory of Samothrace. Headless, mutilated though she is, no one can mistake the triumph, the elation of the pose; no one can fail to hear the whistle of the wind beating helpless against her advancing pinions. And the Venus of Milo—that beautiful inscrutable woman who has puzzled the world for nearly a century? Surely she has been a living goddess to all who have seen her, a block of marble to none. You shall hear the story of her

discovery, and the romantic sequel that has recently come to light. It was admirably told in *Chambers's Journal* for August, 1913:

" . . . Early in 1820 a peasant of Castro, in the Island of Melos, also called and spelt Milo, at the entrance of the Greek Archipelago, was digging over a piece of land which he possessed on a small hill-side. He was named Yorgos Bottinis. With him were his son Antonio and one of his nephews. The spade of one of the three broke through some dry débris and revealed beneath their feet a kind of crypt or passage of masonry. Into this the trio cautiously ventured, and then, in the dim, grey light, they beheld a white figure, the statue of a woman much larger than life size. It was receiving the first ray of light for perhaps over 2000 years. The bust was nude, but from the waist descended a drapery retained from above by the right hand, while the left arm, half bent, was raised, and the hand held a small sphere. The evidence of the three men on this point is vitally important, and it is established beyond doubt. . . .

" . . . In April of the same year a French naval vessel called at the Island of Milo on her way to Constantinople. On board were a young lieutenant named Mattere and a young ensign named Dumont D'Urville, both lovers of art and keen in their search for antique sculpture. They learned here that Bottinis had made a find, and in eager haste visited his hut, and in that strange environment, amid the fumes and dirt, the noble statue of Venus confronted them. Concealing their delight they hastened to Constanti-

nople and assailed, in their ecstasy, the French ambassador, to such purpose that the latter instructed his secretary to repair at once to the island and secure the statue. However, the secretary, M. Marcellus, did not reach Milo until the 23rd of May. He sailed in a small French naval vessel, *L'Estafette*, under Commandant Robert; but when the anchor was cast they were already too late—or so it appeared.

"Near the shore was a Turkish brig ready to sail at any moment, while on the shore was a group of Turkish sailors engaged in towing a large white form towards the waiting vessel. From the bridge Marcellus perceived all this at a glance. It was the Venus of Milo, lost to France for ever, unless—— Neither the Commandant nor Marcellus wasted words; there was no time for reflection. At the order of Robert, the sailors of *L'Estafette* hurled themselves into the boats, drew to the shore with all possible speed, and with drawn sabres engaged the abductors of the Venus. The statue had been mounted on a primitive kind of wooden sled and secured to it by ropes. Around this a warm encounter took place, and after a few minutes the French sailors were left in possession. But the position was not secure, and a return of the enemy reinforced from the brig was feared. The task of the sailors was therefore clear, and they bent to it with a will.

"Already the sled on which stands the statue—or rather, the bust, for only the upper portion is here—is considerably damaged, and as the sailors put their shoulders to the ropes the statue sways ominously and then falls on its back. But there is no

time to lose. The sailors seize the ropes binding the statue to the sled and pull with increased vigour. Alas! the result is a tragedy, agonizing as one thinks of it. The beautiful white shoulders grind over the sharp stones of the rough path, and portions of the marble are broken off. But the sailors cannot stop for such a detail; they carry out their orders with a brutality only equalled by their courage and promptitude. The broken fragments are hastily picked up, and at last the goddess is on board—without arms, it is true; but there are the fragments also, and they can be restored later. The essential is to have the Venus.

"But unfortunately only the bust is gained as yet; the lower part of the statue is already on board the Turkish brig. It is only after two days of argument, and of money and force alternately, that Marcellus succeeds in obtaining the statue in its entirety. But no, not in its entirety; for on the strand of Milo were left some priceless fragments of marble by the careless sailors. The fragments saved, one arm, one hand, and other unrecognizable portions were just sufficient to give free rein to the imagination, and when the statue, in this mutilated condition, reached the Louvre without explanation, supposition was piled on supposition, hypothesis on hypothesis.

"The uncertainty would have been ended by a word from Mattere or D'Urville; but then the whole incident of the Island of Milo would have been revealed. And so, in fear of diplomatic difficulties, silence was maintained by all the actors of the little drama. For half a century the facts were known only in one

government's Foreign Office; but the facts were committed to paper by Dumont D'Urville, only to be revealed to the riddle solvers after nearly ninety years."

The study of crystals is too elaborate and complicated a science to be dealt with here; for we should find ourselves wandering in the mazy paths of geometry and chemistry instead of in the well-filled halls of our treasure-house. But it is unfair of me to tell you that marble is a crystalline form of limestone without going a little farther into the subject. The term crystal is generally applied in a loose kind of way to any mineral substance that is hard and clear, but that is a very inexact definition. In the language of chemists, a crystal is a piece of matter of definite geometrical form, with plane faces. Crystals may be made by chemical precipitation from water, by the process of cooling from a molten state, or solidifying from a fluid one; or by the enormous pressure resulting from the great upheavals of the earth. The simplest way for us to observe the formation of crystals is, if we have sufficient fortitude, to watch a thin layer of water freezing on a cold night. The name crystal is derived from the Greek "krystallos"—ice, as the ancients believed that all rock crystals were the ultimate result of frozen water. Now we know this idea to be erroneous, but we still class as crystalline rocks ice and snow that never melt, such as lie above the level of perpetual snow in mountainous regions and in the Arctic and Antarctic zones. Besides ice there are two forms of crystal with which everyone is familiar, namely, sugar and washing soda. Most

beautiful crystals may be seen by magnifying a flake of snow. Snow crystals are all six-sided, but you will never find any two exactly alike in shape. Sometimes they are solid hexagonal figures on which the microscope reveals delicate patterns. Others have six rays springing from a solid centre. Yet another group produces six branches from each of the six rays, while others develop the rays into six-sided stars. Mr. Wilson A. Bentley, an American, is he to whom we are indebted for our knowledge of snow crystals, for he has taken no fewer than 2000 photomicrographs of perfect snow crystals. As all snowflakes do not provide perfect crystals—in fact, perfect specimens are difficult to find—and as the photographs must naturally be taken in a temperature not higher than 32° F. you will appreciate the difficulty of Mr. Bentley's labours. It is interesting to note that the lightest form of crystals, when the six rays just join at the centre, fall from low-lying clouds that are not very cold. Those with a better-developed centre, which provide the most effective of the snow-crystal patterns, come from colder regions. The compact solid forms may come from a great height, as much as 7 or 8 miles, and will grow and develop for days before they finally drop to earth.

The growth of crystals is one of the most interesting things in natural science. Indeed, the three processes that are characteristic of the simplest forms of life may also be observed in crystals. Just as living things grow by absorbing food internally, so crystals grow by adding to themselves externally; and as organisms can reproduce themselves, so does a crystal, when it

is full-grown, concentrate its energy on forming a new crystal beside itself. The point at which a crystal is full-grown depends upon the species. The largest known crystals are beryls, which may reach 2 or 3 tons in weight, but others are quite tiny, the average size being less than a quarter of an inch.

No one needs to be told that quarrying is one of the greatest industries in the world; and no one who has ever seen quarrymen at work will be surprised to hear that it is the most dangerous. There is death in a false step when you are working at the face of a cliff, a sheer perpendicular wall above and beneath you, and only a rope and your own coolness to hold you to life. And when you have been at the work for half a lifetime you become careless and grow to ignore even safeguards that to a looker-on seem very slender threads of safety. The fellow working above you may dislodge a stone that, in falling, happens on your skull, and makes a nasty mess of it; and although obvious precautions are taken to avoid accidents of such a nature, remember that it is the unexpected that most frequently maims or kills. But the heaviest casualty lists are due to the blasting of the rock to loosen it. Blasting is a necessary proceeding in every hard-stone quarry, and the startling intermittent "booms" from the shot-firing are familiar to all who live within 10 miles of a quarry. As a matter of fact, the good stone is blasted as little as possible, for the very simple reason that the explosions shatter and spoil it; and the charges are confined to the getting rid of the rubbish that exists in all quarries and hinders the mining of the good stone.

Quarry blasting—or shot-firing, as it is more often called—is an interesting aspect of quarrying, and one which we may spend a few minutes to watch. In the first place, then, let us have a look at the blasting agents themselves, since they play so important a part in helping us to redeem the treasures of the earth: indeed, I should think that all the thousands of tons of high explosives stored in the magazines and arsenals of the armies and navies of the world must be a very small proportion of the total that is used in the arts of mining and quarrying. An explosion is a very wonderful and mysterious thing and yet a very simple thing. To the question "What is an explosion?" every one of my readers who has been through a course of elementary chemistry will have ready the reply: "A rapid combination with oxygen of various combustible substances". You know that oxygen is necessary to combustion; that when iron combines with oxygen it burns very slowly, forming rust; that when we burn coal-gas in combination with a precisely-regulated quantity of air we can cook our dinners by the heat of the combustion; that if we leave the gas tap open, so that the gas diffuses with a great amount of air, and then apply a light to the mixture, the gas combines so quickly with the oxygen that it blows the roof off the house. If you drop a lighted match into a can of paraffin the match will go out, just as it would if you dropped it in water[1]; but if you turn the paraffin

[1] Please do not attempt this experiment, for you cannot be sure that the surface temperature of the paraffin is below the flash point; in other words, you may come to a painful end.

C 708 Photo. Underwood

TRANSPORTING CARRARA MARBLE

These famous quarries being close to the sea, transport is simplified and cheapened. There are at Carrara and Massa 400 quarries, and they have been worked for 2000 years.

into vapour and mix it quickly with air, so that the mixture when ignited expands with explosive force, you can drive machinery with it. The internal-combustion motors that act in this way to drive ships, or vehicles, or aeroplanes are called explosion engines, because impetus is given to the piston as a result of the rapid expansion of gas and air caused by the sudden ignition, instead of the steady expansive push that takes place in the cylinders of a steam-engine. So an explosion is nothing more than a very rapid expansion of gases caused by the ignition of certain substances that have the power of giving up vast quantities of oxygen. How rapid this expansion is you may judge when I say that a dynamite cartridge explodes in the twenty-four-thousandth part of a second. If you laid a mile of dynamite cartridges in a continuous line, and fired them from one end, the whole mile length would have blown up in little more than a fifth of a second—before you could say "Jack Robinson", in fact. And dynamite is one of the least rapid of modern explosives. There are indeed some explosive agents known to chemists that are so violent as to be quite useless for practical purposes. And there are others used for surface blasting that could not be used in warfare, because they explode so rapidly that they would burst the gun in which they were used, before the projectile had time to escape.

Dynamite is a preparation of nitro-glycerine—that is, glycerine that has been treated with nitric acid—and an infusorial earth called *Kieselguhr*. It is mainly to Alfred Nobel, a great Swedish chemist and explo-

sives manufacturer, that we owe the terrible agents of destruction that enable us to tunnel through the hardest heart of the mountain and to accomplish a thousand other feats of engineering that you can think of as easily as I can. Before Nobel's researches commenced, nitro-glycerine was the only blasting agent known to us that was more powerful than gunpowder. This nitro-glycerine was an oily liquid so dangerous to handle that its use was ultimately forbidden in practically every country in Europe. Nobel set to work to discover some absorbent substance, inert in itself, that when mixed with the nitro-glycerine would render it safer to handle. *Kieselguhr* was what he ultimately chose. This material is composed of the hard remains of our old friends the Diatoms, the stalks of which consist principally of silicon. Nobel called his preparation dynamite, and for many years it held first place in the list of high explosives. The trouble was that, though it made it much safer to handle, the infusorial earth took away from the nitro-glycerine a good deal of its explosive force. So Nobel proceeded to invent a new explosive of frightful power. He mixed nitro-glycerine and collodion, which is gun-cotton dissolved in ether. Gun-cotton, or nitro-cellulose, treated with camphor to make it non-explosive, is the common article of commerce known as celluloid.

There are many stronger explosives than dynamite and the "blasting gelatine" just described, as, for example, the picric-acid preparations. Picric acid is a coal-tar product that was once largely used as a yellow dye. It needed a terrible dye-works explosion

to draw attention to its explosive properties; but as it is only used in warfare for bursting charges in shells, I shall not attempt to describe it here. It has been tried for blasting purposes in quarries, but its great drawbacks are its shattering effect on the rocks and the poisonous qualities of the dense fumes that result from its explosion. This matter of the discharge of fumes is one that has to be studied carefully. Fortunately all high explosives are controlled, both in their making and use, by Government officers. There must be many persons who can still remember the Crarae quarry disaster of 1886. At this quarry, which is in Argyllshire, it was necessary to remove a great mass of granite, and it was hoped to accomplish the task at a single effort. More than 6 tons of explosives were arranged to be fired at once. The rumour of a "big bang" brought to the scene a great crowd of onlookers. The charges were fired, and 60,000 tons of granite were dislodged. As soon as the explosion was over the crowd surged into the quarry to get a nearer view of things, heedless—or ignorant—of the presence of vast volumes of poisonous gas. More than fifty of these stupid people were overcome and fell unconscious, and seven died of suffocation before help could be brought to them.

The method of using the blasting charges varies greatly in different quarries. In what is called the small-shot system the area of rock that it is desired to blast is first drilled with a number of holes. The holes are generally arranged in the form of rings, and are nowadays drilled by electric, or compressed-air, or hydraulic-drilling machines, seldom by hand

in the large quarries. The holes are only about 1 inch in diameter, but they may extend into the solid rock for several feet. When all the holes have been made and cleaned out the shot-firers insert the charges, and connect them all together with electric wires. A signal is given to all the men working in the neighbourhood to get to a place of safety, and the charges are fired by electricity from a spot a long distance away. Then, after the explosion, when the clouds of dust have had time to settle and the foul gases to disperse, the men return to the scene. The rubbish is loaded either into trucks and run to the spoil banks, or it is passed through machines with powerful jaws that break it still smaller, so that it can be used for road-making. Or again, if the quarry is of limestone, it may be burnt in kilns to produce lime, a material which, as you know, has a thousand uses—mortar, cement, iron-smelting, glass-making, gas-making, alkali-making, candle-making—indeed, there seems no end to the list. But if the stone is to be used for building the blocks are hewn into workable sizes with hammer and wedge, and then lifted by derricks on to trucks, and so carried to the dressing sheds. Here they are sawn to shape, the kind of saws used depending on the hardness of the rock. Sometimes saws without teeth are used, the action being a sort of rubbing, or abrading, that cuts through the hardest stone. In some yards you will see (and hear) what seem to be circular saws simultaneously cutting several slices from a single block of stone. These saws have diamond dust on their edges, and provide the most suitable instruments yet invented for cutting hard stone.

Certain acids will eat away stone, and cause it to decay quickly. The atmosphere of London and other large towns is laden with sulphurous-acid gas from their millions of smoky chimneys, and this is the agent which acts so disastrously on stone buildings. It is possible to turn this quality to good account, as the lithographer does when he causes nitric acid to eat away the parts of his stone not covered with drawing. Nature, however, has used it in the making of some of her wonderlands. Carbonic-acid gas is, as you know, one of the constituents of the atmosphere. It is also present in the soil, as a result of decaying organic matter. All water, therefore, that falls as rain and sinks into the earth is more or less impregnated with carbonic acid. When rain falls the water sinks into the ground until it reaches a layer of clay or impermeable rock, when it runs along until it finds an outlet. Sometimes water from a large area will collect at the same spot, and an underground stream is formed. If the rock through which it flows be limestone, and if the stream carries a great deal of carbonic acid, the rock will soon be dissolved, and the stream will carry bicarbonate of lime. In the course of ages the stream hollows out a channel for itself. It follows the bed of limestone, and winds and burrows under the earth in whatever direction the rock may take. In years to come possibly the stream is diverted or drains off to some fresh channel. It leaves behind it a monument to its workings in the form of a cave or subterranean passage. Caves of this kind are to be found in the British Isles, but the most wonderful is the Mammoth Cave of Kentucky.

This is one of the sights of the world, one of Nature's greatest marvels. White men discovered its existence little more than a hundred years ago, though traces of human habitation of great antiquity were found. Even now no one knows the entire extent of this extraordinary series of caverns. Some of it has been mapped, and it has been estimated that one can walk, climb, and float nearly 160 miles underground. What is most remarkable is the wonderful beauty of the caves. No human architect ever could have designed the domes and arches save in a dream. Yet the work has all been performed by a very humble instrument—water incessantly trickling down to join the Green River and its branches. This water is charged with carbonic acid, and by dint of running and dropping for uncounted thousands of years it has succeeded in hollowing out the hills which fringe the Green River at this point. The river itself has worn a valley hundreds of feet deep.

The wonders to be seen within the cave defy description. The water, you see, has not cut a smooth, clean surface, such as you find in sea caves. It has been capricious and uncertain in its action. The result is a number of different effects. Sometimes you meet masses of rock cut into pinnacles and towers; veritable magic palaces and castles they seem to be. In another place the carving has been done on a finer scale, producing delicate traceries worthy of a cathedral. Or arches and galleries ornament a great dome; in fact, one dome is called The Church, and services are held there sometimes. The highest of these domes is 250 feet from floor to roof.

The largest, to which the name of Chief City has been given, is 500 feet long and 280 feet broad, while the height averages 100 feet. In the Mammoth Dome, six mighty columns, each 80 feet in height and 25 feet in diameter, support the roof on one side. These pillars have all the orthodox points, fluted columns and distinct capitals being visible. But the cave is not made up entirely of domes and great chambers. Passages and corridors lead from one to another. Some of the passages are extremely narrow and tortuous, one in particular being called the Fat Man's Misery. Another is a beautiful, spacious avenue extending for several miles.

Yet another feature of the cavern is its water-ways. The main river is some miles in length and has numerous tributaries. In several places it broadens out into large lakes. One of these, named the Dead Sea, is bounded by dark cliffs, from the top of which it is impossible to see more than a small area of the lake. From these cliffs you pass on to a natural stone bridge over the River Styx. The guide stamps on the bridge, and the sound reverberates through the cave like the beating of a great drum. The path by Lake Lethe is so narrow that visitors have to walk in single file, but it takes them to the Great Walk, which no one would like to miss. This avenue is 90 feet high and three-quarters of a mile long. Its floor is of clean, bright sand, and it leads direct to the banks of Echo River. This, to my mind, is the most romantic part of this abode of faëry. Echo River was for long too sinister and ominous to be ventured upon; but at last, many years after the

discovery of the cave, a negro trusted himself to the dark waters. His discoveries were amazing. Now, if you are a courageous visitor, and the river is not swollen, you take your seat in a big flat-bottomed boat, the guide shouts "Right away!" and off you float into the darkness and mystery. (Timid visitors follow the course of the river on dry land, by a path specially cut for them.) Your boat carries lights fore and aft, but they do little to break up the blackness; in fact, they only seem to accentuate it. Presently you become aware that you are passing under a great arch, and immediately the character of your voyage changes. You are awed no longer. You are delighted, entranced by the clear water, 20 feet deep, at the bottom of which you can see sand and shells. Your imagination is stimulated, not depressed, by the broad waters and the alluring side channels. But more wonderful things are to come. You land after a voyage of three-quarters of a mile, and make your way to Cleveland's Cabinet. A prosaic name enough for the nearest approach to fairy halls that any grown-up is ever likely to see. The Cabinet is 2 miles long, and the walls are entirely covered with jewels and precious stones. The guide will tell you they are crystals of gypsum, but you and I know better. Anyhow, the place sparkles and glows marvellously, and we can hardly take our eyes away. After this the other marvels we are shown seem tame, even though we have to climb the "Rocky Mountains" to look down into the "maelstrom" with its wonderful translucent stalactites.

CHAPTER VIII

Light from Darkness: the Wonders of Oil

Do you know anything about the Parsees? The word means the people of Pars, or ancient Persia, and their religion was once the most powerful in that part of Asia known as Irania. In the early days of Christianity they persecuted Jews and Christians alike; later on, they themselves were persecuted by the Mohammedans. The strong members of the sect fled to India, the weak ones embraced Mohammedanism. Less than 10,000 Parsees now remain in Persia.

What has all this to do with oil? Well, there is more connection than appears at first sight. The Parsees worship a deity named Ahura-Mazdâo, whose symbol is the sun. Equally, flames of any kind are his symbol, and in the Parsee temples holy fires are for ever kept burning. Once upon a time, about 2500 years ago, a Parsee pilgrim was trudging wearily along the western shore of the Caspian Sea, when suddenly he beheld a sight which dispelled his toil and fatigue as by magic. He had found a miracle! From the solid rock a flicker of flame and a column of smoke arose. Without a doubt it was a heavenly fire, for what earthly flame could feed upon the rock? The pilgrim went quickly

to tell his brethren of the miracle, and the place became a goal of pilgrimage. A great temple was built there, of which, we hope, our pilgrim was made high-priest. To this day Parsees visit the spot to make obeisance before the sacred fire; but the temple is no more. Its site is occupied by—an oilworks!

The pilgrim had discovered no miracle. The oil, bubbling out from the earth, had become ignited spontaneously, and so long as the oil flows the fire will never go out. Yet it was hundreds of years before men discovered the secret. Oil was an article of household use from very early times, but it was not mineral oil. Woman, who inaugurated agriculture, probably was the first to discover the presence of oil in certain seeds and fruits; and before then animal fats may have been used for lighting. The Egyptians, the most advanced of ancient nations, made use of petroleum, as did the Incas of Peru, the Aztecs of Mexico, and primitive Chinese and Japanese. But none of these peoples had any idea of the possibilities of the product. How could they, since they had not the gift of prophecy? They regarded it simply as a substance useful for healing wounds and soothing the pains of rheumatism. Possibly they used it to make a crude kind of light, but the oil in its raw state would give only a very smoky, smelly flame. We must consider the petroleum industry as entirely a modern development, and one that, in the space of fifty years or so, has revolutionized the trade and commerce of the world. For not only does it provide the poor man's light, in the form of oil or of candles; it drives our motor-cars, our motor-boats and flying-machines, while sta-

tionary engines of all kinds throb and buzz in response to the explosion of a drop of petrol or paraffin. It allays clouds of dust on our roads, and stormy waves at sea. Scents and cosmetics, dyes and inks, alike owe their being and cheapness to the petroleum well, while there are numbers of articles which never could be made without it. Our asphalt streets and the rubber tires which roll so smoothly over them are two more luxuries which we owe to petroleum.

Whence, then, has this wonderfully-useful substance come? What made it, in those dim periods when the earth was solidifying and taking shape? These are questions which no one seems able to answer definitely. It is hard to understand, but nevertheless it is a fact that beneath the surface of the earth are billions of tons of oil which have accumulated nobody knows how or why. Of course there are theories, shoals of them. Professor A says one thing, and Professor B another, while Professor C declares that they are both wrong, and that his is the only reasonable solution of the problem. Oil differs obviously from minerals such as coal or marble in that it is liquid, while they are solid. Fossils and markings in rocks enable us to trace their age and origin, but there are no such evidences in oil. However, it must have developed somehow from something, and for many years chemists have been at work trying to establish the natural history of oil. Three of the most famous of modern chemists, amongst many others, have held the view that oil is the result of the action of steam on metallic carbides. We know that deep down in the earth there is plenty of steam of very high temperature which,

given the opportunity, certainly would produce some change in the metallic carbides. Dmitri Ivanovitch Mendeléef, who discovered and formulated the Periodic Law of the atomic weights; Pierre Eugène Berthelot, from whose observations was developed the new science of thermo-chemistry; and Henri Moissau, who made artificial diamonds and effected great improvements in the manufacture of acetylene, all supported this theory. Moissau, indeed, went further, and actually produced a substance similar to oil by treating certain metallic carbides with water. But there is one great difficulty in the way of accepting this theory unreservedly, and that is, that we have no knowledge or proof of the existence of such enormous deposits of carbides. Besides, oil is peculiar in that a certain stratum of limestone or sandstone will be oil-bearing, while above and below it are strata that are not oil-bearing, although in every other respect they are identical. For this reason authorities now claim that oil has been formed in the stratum in which it is found, and has never filtered through from any other.

Some chemists assert that oil was formed by the intrusion of igneous rocks into deposits of shale, coal, or lignite. Such deposits, they say, became heated by the tongues of igneous rock, and gave off their hydrocarbons in the form of oil. But they do not tell us what has become of the residue of the coal or lignite, and it is not conceivable that half the interior of the earth could undergo distillation without being found out. The most substantial of the theories is that which ascribes to oil much the same origin as to coal. Round about the great oil-fields

we find fossilized remains of marine life and great deposits of salt. It is believed that when our seas were great shallow lakes rather than oceans they swarmed with minute forms of life—diatoms, foraminifera, and such things. The first generation of these creatures died and sank to the bottom, to mix with sand and silt and presently to be covered by the bodies of the next generation. In this way were strata of limestone and sandstone formed, and it has been said that ages of pressure and a rise in temperature led to the conserving of oil in some of the strata.

Be that as it may, what men of the present age are concerned with is, not how the oil got there, but how to get it out again. We shall see that not only has the increased output of petroleum revolutionized the manufacture of countless articles of commerce; it has also called into being new apparatus, new appliances, and above all new means of transport. It was a new commodity, and when once its possibilities appeared the best brains in the world turned their attention and ingenuity to deal with the problems it presented. The history of the petroleum trade is all recent. We cannot trace it farther back than the 'forties, although, as I said before, many ancient peoples undoubtedly made use of petroleum.

The first episode in the story begins with the birth of James Young, of Glasgow, in 1811. James was the son of a cabinet-maker and was expected to follow the same trade, but fortune had other things in store for him. After working all day at joinery he would spend his evenings at the Andersonian University and the Mechanics' Institution. Chemistry was his favourite study, and so wonderful were his persever-

ence and progress that in 1837 he obtained a post at University College, London. He did not, however, remain there long, for we hear of him as manager of a chemical works near Liverpool in 1839, and a few years later as holding the same position in a works near Manchester. His genius first asserted itself in various directions with which we are not concerned, but in 1847 he received a letter which determined his life for him and resulted ultimately in the establishment of the paraffin trade. The writer of this letter was Dr. Playfair, and he desired to call Young's attention to a dark fluid which had been found in a coal mine at Alfreton in Derbyshire. Young went to Alfreton and pronounced the liquid to be oil.

He immediately realized how valuable this substance might become, and after a great deal of difficulty he managed to build a refinery. Here he produced three commodities, a heavy oil for lubricating, a light oil for burning in lamps, and paraffin wax. This spring only flowed for two years, during which time it produced on an average 300 gallons a day. Mr. Young then transferred his energies to the Scottish shales and put up a works at Bathgate. A patent was given to him for the process of distilling oil from cannel-coal, and he was able to grant licences for the use of this process to firms in the United States. In 1859, however, he found a rival in the person of Mr. Robert Bell, who started a works at Broxburn for the distillation of oil from shale. This substance soon proved itself capable of giving better results than coal, and since 1862 nothing else has been used in Scotland for distilling oil.

The oil produced in Scotland goes by the name of paraffin. This name was invented in 1830 by Baron Reichenbach, who used it to designate a substance he had obtained from wood-tar. It is compounded from *parum affinis* — being what Lewis Carroll would have called a portmanteau word — *parum affinis* having little affinity for an alkali. An identical substance was made about the same time by a chemist of Edinburgh named Christison. Christison was making a study of Rangoon petroleum and succeeded in obtaining paraffin, but he called it petroline. In France, the chemist Dumas produced the same compound from coal-tar some five years later. But for the fifteen years intervening between the discoveries of Dumas and James Young, paraffin wax was regarded simply as a chemical curiosity. The commercial products which now depend on paraffin wax for their cheapness, in some cases for their very existence, were unknown or beyond the reach of any but the wealthy. Yet it is problematic whether these articles ever would have been discovered if the Scottish oils had been able to keep their place in the market.

From 1850 to 1864 the Scottish lamp-oil had practically a monopoly of the trade. The manufacturers were making fortunes out of it and did not trouble their heads about side-products. In 1859, however, Colonel Drake struck oil in Pennsylvania and shortly afterwards the markets were flooded with cheap petroleum. Scottish paraffin went down and down. Many of the small firms were ruined, only the very largest and most solid being able to keep afloat. The manufacture of Welsh coal oil collapsed, never to revive.

It was in these circumstances that new prophets arose. Threatened with ruin and disaster, the heads of the business began to examine their waste. What, they asked, goes into our dust-bins, and can we not find some more profitable way of disposing of the rubbish? The brains which saved the situation were those of N. M. Henderson, George T. Beilby, and William Young. Their labours resulted in a complete change in the working of the refineries. Light oil for burning retired from its place in the front rank of oil products, while an increased quantity of heavy oil for lubricating was produced. Paraffin wax was brought into prominence, and sulphate of ammonia was a by-product which rapidly became valuable. Moreover, new forms of retort were introduced which effected a great saving in labour and coal.

At the present moment the subject of oil fuel occupies a large space in the brains of the nation. The perfecting of the Diesel engine and the inclusion of oil-driven ships in our navy necessitate an enormous increase in our oil bill. Unfortunately, however, our oil has to be transported from abroad, a state of things almost suicidal in the event of war, necessitating storage in this country on a colossal scale, and entailing the use of a large number of our cruisers to prevent the interception of supplies. Obviously, with oil rapidly becoming the predominating fuel of our fleet, it is now as necessary to provide a home supply of oil as it was in the past to provide our own coal. The question is, How can this be done without natural springs? Fortunately for us the prospect of this home supply of oil has become, not a remote possibility, but an absolute certainty. Apart from the output from the

Scottish refineries, the product of which is at present too limited and too expensive to be taken into serious account, we have a home industry recently started which promises to supply in almost unlimited quantities a cheap fuel oil of the highest quality.

It is in the utilization of the oil contained in England's vast coal-beds, and in the unlimited deposits of shale, peat, and lignite, all of which can be distilled to produce oil, that a way out of what may well be termed a national difficulty will be found. A company known as Oil & Carbon Products, Limited, exploiting the Del Monte process for distilling oil from shale, coal, peat, &c., has found a way to utilize these resources of oil to the best advantage, and is at present working on the shale from Brandy Bay in Dorsetshire. As much as 80 gallons of oil and 34 pounds of sulphate of ammonia are being obtained per ton of shale, while the cost of refining the oil is as low as ¼*d.* per gallon. The shales in Brandy Bay possess the advantage of being found on the surface, and are obtained by mere quarrying with a steam shovel. The first cost is thus only 6*d.* per ton as compared with 5*s.* per ton in the case of Scottish shales, which have to be mined at depths ranging to as low as 3000 feet.

In the Del Monte process the time of distillation occupies only from forty-five to seventy-five minutes, and as the heats are graduated and range from 100° F. to 900° F. every particle of useful oil is recovered in the state of its first formation without being changed into tar by the action of higher temperatures. The oils, in fact, are of the true paraffin series, and thus, by means of the Del Monte process, our coal-fields

and deposits of shale and peat will become our home oil-fields. The process provides a means for using the waste slack and coal-dust from the collieries, thereby adding to, rather than diminishing their revenue.

Petroleum is the name by which the oils of America, Russia, and other countries are known. The two names petroleum and paraffin signify the same substance, the only difference being that of the locality in which they are found. The history of the American oil fever, as romantic a one as any boom of gold or diamond fields, begins in 1859. Of course we know that the oil was used away back in the Dark Ages by the primitive men who preceded the North American Indians. We are too apt to think of America as a country without a past. There are wells still existing in Pennsylvania in which trees 1000 years old are growing. These wells must have been dug by the mysterious people we call the mound builders. These people dug copper on the shores of Lake Superior and lead in Kentucky, while there are evidences which show that they took mica from the mines of North Carolina. Nothing easier than for them to dig a hole in Pennsylvania and dip out the oil which collected in it. But it was not until 1850 that any systematic attempts were made to use the oil lying at the bottom of the old wells, and even then the experiments were futile and unsatisfactory for close upon ten years. The Pennsylvania Rock Oil Company was incorporated in 1854, and Colonel Drake was appointed superintendent. For four or five years his work was disheartening in the extreme. He knew the oil was there waiting to be collected, but he could not persuade it to come to the surface. It is said that he

was actually looking for brine when he made his great discovery. However that may be, it was on 28th August, 1859, that he found oil rising in an iron pipe which he had sunk to a depth of something less than 100 feet. Needless to say, he could not keep his discovery secret. Prospectors rushed to the spot and soon the whole district—that is to say, round Titusville, Oil City, Oil Creek, French Creek, and the banks of the Alleghany River—was transformed from forest to mining camp.

Innumerable springs of oil were tapped, some at a great depth below the surface, yielding large quantities of oil without pumping. Others were only of moderate capacity, and were exhausted after being pumped for a short time, while in some cases likely-looking places proved barren. Fortunes were made in a day, and equally large sums were lost in the same space of time. But an oil-field obviously differs from a gold-field in one particular. The oil will not sit still and wait until you are ready to dispose of it. Once you have found your nugget or your big diamond your money is made and robbery is the only thing you fear. Your oil-well, however, is only a white elephant unless you have an adequate supply of empty barrels. Consequently millions of gallons of oil were wasted. In the first place, the shallow wells which required pumping were provided only with the scrappiest machinery. Leaks and overflows were hourly occurrences. Secondly, the deep wells flowed so abruptly and copiously that the diggers often found themselves possessed of a fountain of oil before they had so much as one barrel to fill. Thirdly, in spite of all this waste, the supply

was far greater than the demand. The price of crude oil fell, and would-be oil-kings found the cost price of the barrels was higher than the market price of oil. This state of things fortunately did not continue for very long. Many of the prospectors got tired and returned to their farming or shopkeeping. The small wells ran dry, and the deep ones, having blown off their surplus energy, required pumping by first-rate machinery. Moreover, the new product having displayed its capabilities, the price began to rise again and the trade was soon re-established on a firmer basis. Meanwhile the oil region spread and altered its locality from month to month. As one spring gave out another would be tapped. Towns sprang up around the new wells and decayed around the dead ones. Pithole City, near Titusville, which in 1865 had the second-largest post office in Pennsylvania, is now a prosperous farm. Hardly a trace of the city remains, and the very fame of it is dim and beclouded.

The United States produces 31,000,000 tons of oil a year. This prodigious amount is equal to 60 per cent of the output of the entire world, and is drawn from the states of Pennsylvania, New York, Ohio, West Virginia, California, Kentucky, Tennessee, Colorado, Indiana, Illinois, Kansas, Texas, and Missouri. But the localities are perpetually changing, and it is hardly an exaggeration to say that every one of the United States is productive of oil. Mexico and Canada also have their oil-fields, though the oil of Ontario is of poor quality, being contaminated with sulphur. The wells of Trinidad and Barbados doubtless will prove very profitable when they are in thorough working order. Russia, Rumania, and

Galicia have the most important oil-wells of Europe, while India promises to provide the largest quantity of oil of all British territories.

The most valuable commodity, however, is of no account so long as it is 100 feet or more below the surface. The only person it can profit is the owner of the land, and it avails him nothing unless he can find a buyer for the property. Many wonderful machines have been invented for obtaining the oil. When we see an oil-field for the first time it strikes us only as a dark, gloomy, squalid, repellent-looking place. We see only a multitude of hideous black derricks towering against the sky, while every step we take lands us perilously near to pools of slimy, viscous mud. If we would avoid these we have to step carefully over piles of loose piping and shabby iron tools, or even the precious pipe line itself. Roads there are none, only ill-defined tracks over the abominable black mud. Sometimes we pass a derrick just as a tool or baler is coming to the surface, and we are lucky if we escape without being splashed from head to foot by the thick murky fluid it brings up with it. We are not imaginative enough to look ahead and see instead of the squalor and filth of crude petroleum piles of glittering sovereigns and crisp bank-notes, smart motor-cars gliding smoothly over asphalt roads, cosy cottages brightly lighted, and whole rows of bottles of clean, wholesome medical or toilet articles. Nor does the cosmopolitan crowd of workmen concern itself with such fancies. It only regards the creature comforts accruing immediately to itself—the good pay and all the desirable things good pay can bring. And I very much doubt whether the purchasers of

half a gallon at the village shop, from which they get a better light for fourpence than their grandparents did for eightpence, ever stop to think of the fertile brains and nimble fingers which have made it possible.

For the story of oil from the time it leaves its native bed to the time its existence ends in bright clear flame is the story of the triumph of man's ingenuity. The engineers of oil-wells had no precedent to guide them: in the early days they simply had nothing but their own wits to help them. For instance, how could one deal with a fountain of oil 200 or 300 feet high? The thing seemed untamable. Once upon a time an Englishman prospecting in the Caucasus struck oil. But, unfortunately, what he struck was a gusher, and it ruined him instead of making his fortune. His gusher was on a hillside, and the oil ran away downhill, killing sheep and devastating acres of fat pasture land. Presently up came the farmers with their little bills for compensation. Nobody could stop the gusher, and the Englishman had to pay and pay until his pockets were quite empty. Nowadays, except in the case of extremely violent gushers, man can capture the fountain. What is called a "casing-head" is placed on the top of the well. This casing-head is fitted with valves of very great strength, through which the oil pours into pipes which carry it to a reservoir. It sometimes happens that the oil brings with it quantities of stones and sand, and no valves or casing are strong enough to stand the prolonged battering which then results.

But gushers are capable of bringing about an even greater catastrophe than the destruction of a farm or

C 708

THE LAKEVIEW GUSHER, THE MOST REMARKABLE OIL-WELL IN THE WORLD

Situated in the Maricopa Oil-field, California, this well yields over 40,000 gallons a day from a depth of 2300 feet. It can be heard roaring for more than a mile.

two. One of the most awful sights in the world—an oil-field on fire—may be caused by a gusher. The uncontrolled fountain of oil somehow becomes lighted. The river of flame rushes along, lighting pools and other streams of oil on its way. The wooden derricks catch fire and blaze merrily. The scene is terrifying: columns of flame leap up against a dark, lowering background; clouds of black smoke form and slowly fall earthwards. The cries of the workmen and the roar of the flames add to the horror and confusion. Yet man has devised means for checking even such a terrible outburst. If it be possible for the workmen to approach the mischievous spout its doom is certain; they will extinguish it somehow. They may direct jets of steam into the flames, or they may drag a huge bundle of iron rods of enormous weight across the spout. Another appliance consists of a little trolley carrying a crane, which runs along on rails. At the jib of the crane hangs a huge iron cap. When the offending spout is reached, the rope holding the cap is released, and the spout snuffs out like a candle.

Fortunately, however, all oil-wells do not gush. The oil, as I told you before, occurs in strata of sandstone or limestone. When these strata were formed they lay horizontally, but by one or other of the processes described in Chapter I they have been transformed into hills or even mountains. Perhaps you know that the upper part of a hill is called the *anticline*, and the lower part, with the valley or trough, is called the *syncline*. In a district where there is oil there is also generally brine. The brine, of course, is heavier than the oil, and lies along the bottom of the syncline. Another accompaniment of oil is natural

gas, which has been generated during the formation of the oil from decaying organic matter. This, being lighter than the oil, floats above it. So we have our belt of oil trying to maintain a comfortable position between the pressure of the brine in the syncline and the gas in the anticline. Now comes the prospector with his boring tools. He drills a little hole, reaches the gas, and pouf! a column of gas, followed by a spout of oil, springs out of the ground. Sometimes the oil-bearing strata have undergone no change of surface and have no anticline. These flat oil-fields are far from being as profitable as the hilly ones, since the oil is spread over a wide surface and is much more costly to collect. The best and most economical well is that which is found in a kind of raised terrace—a formation caused by volcanic movements from two different points of the same strata; the terrace becomes a natural tank, as it were, for the oil and gas. In districts where no brine occurs, the oil collects at the lowest part of the porous strata, that is to say, in the syncline.

It is not easy to detect the presence of oil. Like the other hidden treasures of the earth, it hangs out no unmistakable signals of its presence. The geologist may be consulted, and he may say: "Yes, there are certain indications of oil. Here is an outcrop of strata which may very well be oil-bearing; there is an oily scum on the water in the stream; natural gas is escaping from the soil in one or two places, and the general character of the district inclines me to the belief that it may be petroliferous." Having decided that the prospect is good, the geologist next makes trial borings, which will decide whether oil really is

to be found in profitable quantities. But before he begins he has to make up his mind what tools he will use. You see, there are several different kinds of drills, and each one has its particular virtues. No doubt, too, each geologist has his particular favourites amongst the tools, but his choice must be guided chiefly by the nature of the soil he proposes to bore. In any case he probably will have to employ one of two methods. These two principal methods are called the Percussion and the Rotary systems; the rotary is used for drilling soft strata, and the percussion for hard.

First of all, then, the geologist walks over the ground and says: "We will bore here, with such and such a tool". Next comes the engineer, and over the spot selected by the geologist he will build a huge derrick. The derrick is a proud thing when first it is erected. Its new wood gleams in the sunlight as its lattice-like form grows and grows, ever tapering towards the sky. Its base may be 20 feet square, but its summit, 80 feet above the ground, may be only 4. A few short weeks, however, and the derrick's prime is over. Its loveliness has departed, and all that we see now is a blackened, debased, squalid, crazy-looking structure. It is like a bride who, once the wedding-day is past, takes no further care of her clothes and complexion. "But there!" snorts the derrick. "When you are hauling up 5000 gallons of oil every hour you haven't much energy left for attention to your person. My complexion suffers, but I'm making the vaseline for *yours*. Did you ever know a cobbler who was well shod? No, of course you didn't; and if I had the time I could give you plenty of other proverbs of the same kind. Dairy-

maids hate the sight of cream, sugar-refiners loathe the smell of treacle—here comes the bailer again——" and the rest of the derrick's moralizing is lost in the swish and thunder with which the bailer empties its 300 gallons.

But we are anticipating. The engineer is still at the point of finishing off the derrick, which has not begun to work yet. It has not yet grown tired of lording it over the countryside and admiring the view. Even now, however, its holidays are drawing to a close. Creeping over the plain we see a procession of horses and wagons. The road is rough and progress is slow, but the procession is coming nearer and nearer. At last it arrives at the camp, and the first instalment of that wonderful miscellany known as "plant" is unloaded. The derrick does not trouble itself. A close observer might notice a very slight toss of its head as though it whispered scornfully to itself "Ants!" but as a matter of fact no one bothers to observe the derrick very closely. Everyone is watching the unloading of the plant. For a town has sprung up round the newly-erected derrick—a town of labourers and mechanics, who think, talk, and dream of nothing but oil. The labourers already have been at work digging out the beginning of the shaft. They have reached the bed rock by a hole 8 to 10 feet square, and now that the drills have arrived the mechanics will start their operations. Presently the derrick feels a queer sensation in its inside. There is something particularly queer about this sensation, for it is continually rising. It rises, indeed, to the tipmost top, and there it stays. The derrick feels very poorly all day, but when the mechanics

knock off work in the evening they congratulate one another on a smart job. They have, as a matter of fact, enriched the derrick by two pulleys. Over one of them runs the wire-rope which will carry the drilling tools. The other is occupied by a rope attached to the sand-pump—a necessary part of the plant which is employed to lift water, sand, and fragments of rock out of the bore-hole.

The oil having been drawn up from the earth and sent through the refinery, it still remains to get it to market. It cannot be taken in sacks like potatoes, and barrels or cans are heavy, costly things. A commodity is valuable only when it is in its proper place. The ice at the North Pole is of no use to anybody. If it could be wafted to the United States in midsummer it would be sold for a small fortune; but as things are at present the transportation of ice is a lengthy and expensive business. It requires men and special boats, and there is not such a very big profit coming to the owner at the end of the season. In the same way barrels of oil in the refinery, or 1,000,000 gallons in one of the huge reservoirs which are part of the equipment of a flourishing oil-field, will not fill lamps in Ireland nor drive a motor in Paris. There are no leisured residents in the vicinity of the wells; the country is not enticing. So the brains of man, which were given him to think and overcome obstacles with, have had to devise a means of transporting oil which should be cheap and quick. When the Pennsylvania wells first came into prominence the oil was put up into barrels and carted away on wagons. This method, however, swallowed up all the profits, and in some cases all the capital too, a state of things which did

not suit the keen American directors. It did not take them long to find a solution of the difficulty. "Make it run in pipes," they said. The first pipe line was laid in 1860, and was the forerunner of the network of lines which now connects every oil-field with the world's markets. It was not laid, of course, without a struggle. The wagoners, who would lose their work, objected very strongly, and actually destroyed the line on several occasions. We may be sure, too, that the land-owners, if there were any, wanted heavy payment to allow their land to be cut up and veined with pipes. But progress won the day, and Pennsylvania is now connected with New York and other great towns by 25,000 miles of pipe line. The European and Asiatic fields are also provided with pipe-line systems.

The pipes used are made of wrought iron, and they are placed about 3 feet below the surface, in order that the oil shall not thicken in cold weather. Even so, stoppages are often caused by a deposit of solid paraffin wax. These deposits are cleared away by a funny little instrument called a "go-devil". It is spindle-shaped, with projecting blades. The flow of the oil carries it along and causes it to revolve, so that the blades scrape the sides of the pipe clean. Oil, as you know, is much more viscous than water, and on a long journey it has to be pumped frequently to maintain the flow. There are eleven pumping stations between the Pennsylvanian wells and New York. The pipe line runs ultimately to a wharf or to a railway station. At a wharf the oil runs into great tanks, where it remains till barges or oil ships come to take it farther on its journey. At the great

railway centres the pipe line splits up into a number of feed-pipes, each of which connects with a tank wagon holding from 5000 to 8000 gallons. The train is all ready to start, and all the tanks fill simultaneously. In a very few minutes the pipes are disconnected, the engine whistles, and the train steams out of the station. Not much time is wasted over entraining some 100,000 gallons of oil.

Oil is borne by water in specially-designed boats. The first tank steamer was used on the Caspian Sea, to connect the Baku fields with the mouth of the Volga. Now oil is carried by great steamers on all the oceans of the world. The largest of them can hold some 15,000 tons and can make 11 knots an hour. These great boats can be filled while lying at their moorings a mile from the shore by pipe lines laid on the bed of the sea.

We cannot help marvelling at one thing. These great boats can carry their load of the dirtiest stuff the world produces thousands of miles, and bring back in the very same tanks a cargo of dainty silks, delicate porcelain, and fragrant tea. The getting and refining of oil is a business which blackens the sky and fogs the atmosphere. Nothing pure and white can exist within a mile of an oil well. Yet there is never a spot or stain on these fairy-like eastern fabrics which we gaze at in the shop windows, or buy, if we have enough money in our pockets. You would never guess that they had, as it were, changed beds with 15,000 gallons of slimy, evil-smelling petroleum. A whiff from a paraffin can is sometimes not unpleasant, but a quarter of an hour by an oil ship—no, it is not nice.

CHAPTER IX

The Pocket Genie: Gold and its Romance

It is an amazing thing, but a true thing none the less, that whenever you venture on the statement that there are gold mines within 300 miles of London, nine times out of ten you will be politely disbelieved. Your friends will think you are "getting at" them, or that there is some joke in the business. Gold in Great Britain! A fully-fledged gold mine, with a properly-equipped battery of stamp crushers, capable of dealing with 150 tons of gold-bearing ore a day, within seven hours of Paddington or Euston! Incredible!—though why incredible, goodness only knows; unless it is that the popular imagination only sees gold where it is difficult to get at. But at the Mount Morgan mine, near Dolgelly, in North Wales, £36,000 worth of gold was found in a single pocket about sixty years ago. It was thought that a Welsh Eldorado was found, and there was a regular rush to be first in the new gold-field. Dozens of companies were floated and thousands of pounds' worth of plant was put down; but, alas for high hopes! Reaction set in, and I am sorry to have to record that the Welsh gold-mines are now in a very precarious state. The fact is that there are not many countries in the world in which gold

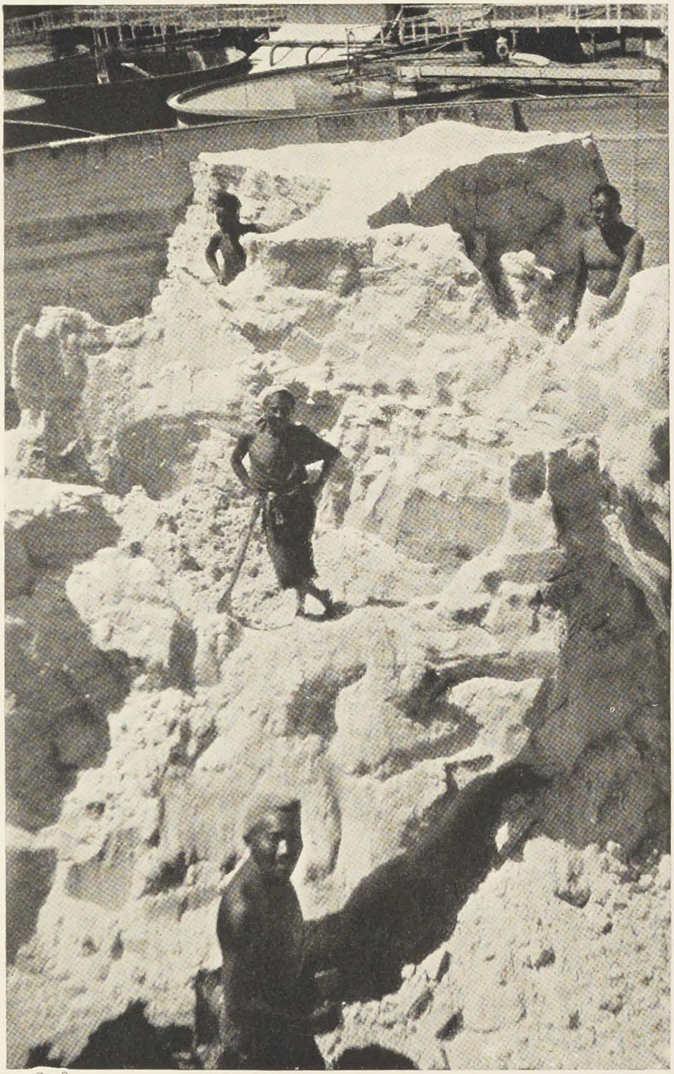
does not exist. The Romans worked gold-mines in Wales, and left behind them many traces of their operations; but it was not until late in the last century that serious attention was paid to the Welsh gold-mines. In the meantime the famous stampedes to Australia and North America had occurred. People were not afraid to venture thousands of miles into the unknown in search of the alluring nugget; but the top of a Welsh mountain and the sands of a Welsh river seemed beneath their notice.

Gold occurs in a number of different rocks apparently of widely-differing formations. Some geologists assert that all gold-bearing rocks are of igneous formation, while others ascribe them to aqueous formation. Probably the truth lies between the two theories. At any rate, amongst others, the deposits in Nevada, Brazil, Australia, and some parts of Europe are of sedimentary origin; while igneous rocks bearing gold are found in Queensland, Colorado, Hungary, Italy, and many other places.

It has been proved time and again that the least-likely places may be rich in gold, and vice versa. A fairly typical formation occurs in the Ural Mountains. In these mountains veins of gold are found in granite and slaty rocks, while "drift"—that is, accumulations of grains of gold and sand—occurs in the hollows of Devonian strata, carboniferous limestone, coal-measures, and Permian rocks. Lodes or veins of gold occur in the older rocks, but, owing to the difficulty of extracting it, these veins were scarcely touched until fifty or sixty years ago. Man's oldest sources of gold are the earth's newest stock. Probably the drift has been washed down from the veins by ages of the wear

and tear of rain, rivers, ice, and glaciers, to be found and appropriated as "placer" diggings. The prospectors have followed the drift up the mountainside until they have reached the parent vein. Nowadays elaborate machinery is set up to work the vein, but this machinery is of recent invention. Gold also is found in the sand of the sea-shore and of running rivers. The River Mawddach—please pronounce it Mouthach—in Merionethshire, is particularly rich. Cader Idris, that great volcanic lump round the base of which the Mawddach flows, is supposed to be largely made of gold, but the difficulty of working it would swallow all the profits.

Gold was one of the first metals to be worked by man. In the first place, as we have seen already, it was to be found in many places within the reach of primitive man. Secondly, it was of great beauty when worked, and was found in sufficiently small quantities to be appreciated; while thirdly, and most important of all, it could be obtained by means of simple appliances such as any man could make for himself. You all know the story of the Golden Fleece? Well, this fleece was by no means a miraculous or extraordinary thing to the ancients. Sheepskins have been used from the earliest times to catch the grains of gold brought down by streams. Before the discovery of America, India was the greatest gold-producing country of the world, and a journey to India from Greece was a much greater adventure than a journey from London to Alaska to-day. We, with our large-scale maps of everywhere, our Cook's and our through bookings, have no conception of the dangers and difficulties of travel in olden days. Still



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A PROCESS IN GOLD-MINING

Chinese coolies in Rhodesia emptying out a cyanide vat after the gold has been dissolved from crushed rock by treatment with cyanide.

greater are the difficulties and discomforts of the poor pioneer in a new land to-day. The rich pioneer, of course, takes his establishment with him. The adventurer, on the other hand, who has no establishment to carry and no home to return to, has to live by his grit and his wit. If he has no grit he will go under; if he has no wit he will come to grief, as did the unfortunate man whose story follows. I quote from *Three Years in the Klondike*, by Mr. Jeremiah Lynch.

"There came to us at Dawson the news of a dreadful death. No one seemed surprised, no one made many comments; it appeared so possible, so natural, so easy to believe, that we simply drew closer to the fire, and wondered where we should be next winter. A miner was walking up the Klondike 10 miles from here going to his claim. The Klondike is fed by numerous soda springs rushing down the banks during the long, hot summer days. These are so potent that even the winter's cold fails to close them entirely. Apparently the soda or alkali in these springs resists the action of frost better than simple water; so, therefore, it often happens that, walking on the edge of the ice near the shore, the footsteps suddenly sink through the weakened ice and into the bubbling alkaline waters that have stealthily worked their way beneath to the deep-flowing stream at the bottom. It was only 6 inches of water that the miner stepped into, and in a moment he was out, and hastening to the brush hard by, started to light a fire; for the clothes freeze, the feet freeze, and in five minutes one may find that part of his body and garments which have been immersed in the water, though only a few inches deep, as rigid as solid steel. Rapidly he cut

a few fragments of wood with his pocket-knife. But the unlighted match dropped from his already chilled fingers, for he had rashly removed his mitts in order to use the knife with more freedom. Then he lighted a second and a third, and finally several at one time; but either his haste, or perhaps a sigh of the air, caused them to fall on the ever-ready snow. And all this time the frost was seizing his limbs, his body, his heart, his mind. He turned to the fatal mitts, which he never should have taken off; but his already frozen fingers could only lift them from the ice where they had fallen, and after a vain attempt he hurled them from him, and strove once again to light a last match. But it was too late. Though only five minutes had gone by, the terror of death was upon him. The ice king slew him with appalling rapidity, and when his companion arrived, scarce fifteen minutes later, he found the body already cold and rigid, kneeling on the snow and ice, while the hands, partially closed together and uplifted as if in adoration or prayer to God, held yet within their palms the unlighted match. They said that particles of the ice-laden air, minute and invisible, floated down to his lungs and killed him as would prussic acid. It was found impossible to remove his arms and hands from the attitude of entreaty in which they were placed, and the body was brought so to Dawson, and later buried without attempting to change their position."

Truly, Nature has set grim dragons to guard her treasure-houses. Worse than the fire-breathing monsters and all the symbolical creatures of the ancients are the invincible laws of the universe. The Gorgon's Head turned men to stone, the cruel cold

turns them to ice less rapidly and more painfully. The country of the Klondike is desolate in the extreme; the climate is merciless; it lies in one of the far corners of the earth, thousands of miles from "everywhere". Moreover, people nowadays are so accustomed to the comforts of civilization that to live in the wilds without any possibility of obtaining these comforts is a hardship unknown by the ancient explorer. It made little difference to the Greek that he would be out of reach of letters for a year or two. The Englishman or American misses his daily newspaper and the postman's visits more than anything. Mr. Lynch draws a picture of men waiting in a queue a hundred yards long to receive their letters. It took two or three days for them all to be distributed, and men high up in the queue would sell their places to those lower down, sometimes receiving as much as twenty dollars. On another occasion a man had a newspaper sent him. He announced that he would read it aloud in the local hall, the charge for admission being one dollar. He had an audience of 500 people.

In other parts of the world where fortunes have been made by the gold-seekers there are other foes to contend with. Tropical heat is perhaps a less terrible condition than Arctic cold. It will not hurt you if you can keep out of its way, whereas cold will have you unless you make efforts to resist it. Nevertheless heat, with its attendant horrors of drought, sunstroke, fever, and thirst, is a very deadly enemy. The lost prospector in the Klondike can generally find the means to make a fire. He who is lost in the sandy deserts of Africa or Australia can find no shade and no

water. The gold-fields of Australia have made many a man's fortune, but they have brought ruin and death to many more. Captain Sturt, in his record of life in the interior, tells us that the average temperature for three months was 101° F. in the shade. The dryness of the atmosphere was such that his finger nails became as brittle as glass. The lead fell out of his pencils, his horn comb split up into thin layers, and wooden boxes shrank so much that the screws in them were quite loose. The tantalizing part is that huge clouds form and seem to presage a storm, but they pass away and not a drop of rain falls.

I have told you already that until comparatively recent times the only form of gold-mine was the "placer" or alluvial digging. When, however, men began to work the veins with improved machinery the production of gold went up with leaps and bounds. Thus, between 1880 and 1890 the average yearly output was £21,738,000; but in 1896 the production reached £45,000,000. It was in that year that Klondike first began to be talked about, and since then the mines in Western Australia and the Transvaal have been opened. The total of the world's output for 1911 was £97,738,000. In little more than twenty-one years the figures have multiplied themselves by nearly five.

Of course the method of obtaining gold in which you have most interest is that which you can perform yourself. I know a boy who once paid his holiday expenses with the gold he obtained from a river. It was in Great Britain, but more than that I cannot tell you. The first thing to do is to find a locality in which gold exists, and that is by no means so easy as

it sounds. For instance, you may find a river which promises well. The surrounding hills may contain gold, and everything may point to the presence of gold in the river. So you make all your preparations and set to work hopefully, but you do not find any gold. Why? Simply because you are looking in the wrong place. Some rivers flow in the same channels year after year, age after age. Others don't, and you have elected to prospect in one that didn't. If you want to find the gold that this river has washed down from the hills you must not look in its present bed, but in the bank of fine sand and gravel it left behind it, ever so many years ago. This sand and gravel may be some distance away, but when you find it you may possibly find some gold. It will be difficult to work without a stream to help you, but if you really mean to succeed you will find a way. Sometimes alluvial deposits are found on the tops of hills, sometimes they run right through the hills and men have to burrow after them. You must never lose sight of the fact that the face of the earth is continually changing; that what was a hill yesterday is a valley to-day, and that what is a hill to-day was sea-level or perhaps below sea-level the day before yesterday. We cannot grasp these enormous lapses of time any more than we can appreciate the vast spaces of the heavens. Our minds are paltry little things, reckoning in tens and hundreds. The billions and billion billions of geology leave us cold. We can only blink, and say "Fancy!"

However, the boy I know who paid his holiday expenses with gold-dust found the right river, and perhaps you may be as lucky. Having found your

river, there are three ways of operating open to you. You may dredge it, you may wait for a spell of hot weather to dry the bed of the stream, you may divert the water into a new channel, or you may simply place an obstruction in the river bed. The first, since you are not a capitalist and have not means to buy dredgers, we need not consider as possible. Besides, it is a clumsy method, though it is the only one suited to a large volume of water, for it leaves a great many grains of gold hidden in crevices of rock. The second is doubtful, for your holidays might be over before the river had dried sufficiently to expose the beds of sand. If it happened to be a very dry year you probably would find this the easiest process, if you could obtain a stream of water for washing the sand. The third way is difficult—too difficult, I am afraid. Besides, somebody might have something to say to you if you started diverting a river. Of course you could dredge up the sand and gravel by hand, and you could improvise a kind of pan, but it would be very hard work. The fourth method will suit you best if the river be not too large for you to obstruct. To perform this you will have to borrow one or more of your mother's blankets. It is not likely that she will lend them to you, but — I can leave it to you. They use ox hides in Brazil and sheepskins in Ladakh and Hungary, but those probably would be even harder for you to obtain than a blanket. The obstruction, whatever it is, must be firmly pegged down into the river bed, and the rush of the water will drive the sand and gravel against it. After some time you will be able to lift it out and you will find a lot of dirt sticking to it. If you have any luck you will find

a grain or two of gold as well. Supposing, however, that you cannot arrange any kind of obstruction, you will have to dredge and wash by hand, as I said before. For this you must have a flat iron pan. The dirt is put into the pan and covered with water. The pan is next shaken with a swirling motion, and the gold, owing to its greater weight, falls to the bottom. By tipping out a little of the dirt at a time, the whole of the gold will be left in a "tail" on the bottom of the pan.

The same principle is applied in all places where alluvial deposits of gold are worked. Flowing water is almost invariably the medium used for separating the gold from the sand. In districts where no water can be obtained a fanning process is employed, but up to the present it has not proved quite successful. Generally speaking, the water is carried to the scene of operations, as being more profitable than carrying the gravel to the water. Where the workings are on a large scale the water may be brought great distances in ditches, flumes, or pipes. Water flowing at a high pressure through pipes is sometimes used to carry away the deposit as well as to wash it. This method is called "hydraulic mining", and it has been practised to such an extent in America that it is now forbidden by law in many districts. So much soil was washed through the sluices that rivers and harbours have silted up, and rich riverside lands have been buried under masses of unproductive earth and rock. The necessity of water to the miners has led to waterworks being built on a gigantic scale, which will be of paramount importance to generations to come, when the gold has all been dug and the miners

are dead and gone. In Alaska and the other northern gold-fields of the world the winter frosts put a stop to these operations. We can imagine how eagerly the spring and the return of the water supply are looked for by the miners. Mr. Lynch gives a description of the method of working frozen ground:—

". . . The method of working I found to be about the same in all: sinking, by burning wood down to bed-rock—that is, 20 or 30 feet—and then running tunnels in various directions along this rocky floor, whereon lies most of the gold. Between the tunnels cross ones were dug, and the dirt, to a height of 8 feet, broken down and taken to the surface, there to lie until washed in spring when water came. We found in one or two cases a decidedly primitive manner of sinking a shaft. It was merely this: flat, circular stones, 2 feet in diameter and 6 inches thick, were heated in a wood fire on the surface for a couple of hours; they were then placed side by side in the bottom of the shaft. It is claimed that these hot stones soften and thaw the frozen gravel deeper and quicker than a wood fire, and that it takes less wood thoroughly to heat the stones than to thaw the ground direct by burning. I doubt this, however. . . ."

Mr. Lynch's doubts did him good service, for when he started a mine of his own he introduced a new process for working the frozen ground. This is what he did:—

"We started on the hillsides two new tunnels, parallel to and equidistant from the old. We did not use the old tunnel, because it was neither in the proper location nor of the proper size. The

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PANNING FOR GOLD IN RHODESIA

Panning is the method chiefly used by prospectors when searching for gold. The earth or crushed rock suspected to contain the precious metal is swirled with water in a flat iron pan. The heavy metal falls to the bottom, and the useless material can be poured away with the water, leaving the gold as a "tail" in the pan.

tunnels, though comparatively dry, yet had to be timbered from the beginning. We sent steam into them through pipes from 1 to 2 inches in diameter. In this, as in everything else, nothing was complete. There was not enough pipe in the country to supply the demand that arose when it was known how much superior was the process of steaming to thawing by wood fires. Our pipe line was 2 inches, $1\frac{1}{2}$ inches, $1\frac{3}{4}$ inches, 1 inch, and $\frac{1}{2}$ inch. We made our own reducers, fitted the various parts to each other, and even made steam-pipe out of rubber garden hose picked up anywhere. Nothing came amiss, and every man had to use his brains as well as his hands. At the end of the drift we pierced the frozen ground by steel points 5 feet long, hollow, with a narrow orifice, from which the steam escaped, and struck the granite gravel. By driving the point gently with a wooden mallet, the steam made its way through gravel and rocks, no matter what size. It was marvellous what it could do. In half an hour there would be three holes 4 feet long and 1 inch wide. The same result under the old process of using hand-drills and iron hammers took seven hours. This improvement was first perfected at our mine, but we asked for no patent. Every miner was allowed to use it, and did so as soon as he knew its great superiority over the 'sourdough' method. Into the holes thus excavated were placed extensions of the steam-pipe. The steam issued from the pointed end and percolated through the frozen ground, thawing and disintegrating. It was allowed to remain ten hours, then withdrawn, and the miners, going at once to work, removed the 4 feet of dirt thus loosened. At least twice as much was accomplished

thus as by wood burning, which up to now had been the universal method of working frozen ground in Alaska and the North-West."

The richest gold-fields of the world are those of South Africa. We can hardly appreciate what South Africa has done to cheapen gold. The huge sums of money it produces from its gold-mines every year have revolutionized commerce all over the world. Everyone feels the effect of this shower of gold. Your mother feels it when she pays a shilling a pound for beef that used to be tenpence; your father feels it when his workmen ask for a "rise"; your uncle in Italy feels it when he uses a nice gold coin instead of the dirty bit of paper which used to be the medium of exchange. In 1910 the output of gold from South Africa was *thirty-two million pounds!* The next year it was more, and it is still steadily increasing. These mines have evolved an entirely new state of things. Controlling enormous wealth, they control enormous bodies of men. Whole towns depend on them for their bare existence. For instance, were the mines at Johannesburg to stop working, Johannesburg would die. There would be no more work for the inhabitants, no more food for the children. There would be *no more money*. But there is no likelihood of their stopping. The mines may be said to have taken their place as an integral part of a highly complex civilization.

A gold-mine on the Rand is a wonderful place. Here we find no bare-armed miners cheerfully panning handfuls of dirt, living a rough, lonely life miles from shops, roads, and railways. Here we are met by a suave manager, who conducts us to an electric

lift, and in a mere second of time drops with us half a mile into the bowels of the earth. When we get out of the lift we find ourselves in a maze of tunnels all lighted by electricity. The lift goes on farther down still, for the workings sink to nearly a mile below the surface. We do not meet many white men. Kafirs and Indians wheel the truck-loads of dirt, or spend their days boring holes in the rock to receive dynamite cartridges.

Trucks of dirt shoot up to the surface, and are seized by Kafirs. In the sorting shed Kafirs discriminate between good rock and worthless. Rock that has gold in it has milky-white markings, and is thrown on to a moving band which takes it right into a pair of horrid iron jaws. The jaws snap and scrunch, and the rock is broken up into small, evenly-sized pieces. Next it passes into a mill and is ground to gravel, when it is ready for the "stamps".

The "stamps" are well named. From the noise we might think it was an army of giants marching. No wonder that the gravel rapidly becomes sand. The sand falls out on to a "pulsator table"—a table always gently moving, covered with mercury. Most of the gold amalgamates with the mercury, but some is left in the sand; but it is not lost. The sand, now called "tailings", is taken from the tables to tanks of cyanide of potassium. It remains there for two weeks, and then the liquid, which now contains the gold, is drawn off and put into tanks containing zinc shavings. The gold adheres to the zinc.

Now we have the gold, but we also have mercury and zinc. The next thing is to separate the three substances. Fire is used to do this. The amalgam

and the zinc shavings are all put into crucibles, and soon a stream of pure gold flows out. The stream fills moulds, and in due time the ingots are packed up and sent to all parts of the world.

The honesty of gold-miners is proverbial. In the early days of the rush to the Yukon the prospectors kept their nuggets and gold-dust in old cans, sugar-bags—any receptacles they could lay hands on—and there were very few door-locks in the camps. Yet the tired miner would go to rest free from all fear of burglars, though he might be surrounded by thousands of pounds' worth of hard-won gold. There are, of course, exceptions to this spirit of honesty, and every reader will uphold the decision recently given in the great Mexican "grub-stake" claim. This was one of the most romantic mining cases ever heard, either in America or elsewhere; and it was tried by four separate Courts of Justice before a decision could be reached. A "grub-stake" is an advance of money made for prospecting purposes, and the chief actors in this case were named Tufts and Hollingsworth. About ten years ago Tufts went to Hollingsworth, who had been a friend of his boyhood, and told him how he had been prospecting in Mexico; how he had struck rich ore; and that he was without the money to start a mine in which a fortune lay. Whether or not Hollingsworth had much confidence in his friend's story, I do not know; but at all events he advanced £400 as "grub-stake"—that is, money to enable him to make a start. Tufts returned to Mexico, and, aided by Fortune, managed to strike a very rich vein. After some years a company was formed to work the mine. The capital

of this company was £2,000,000, and Tufts received £800,000 worth of the stock as his share. Half of this share belonged by right to the friend who had financed him, but the two could not agree, and Hollingsworth was forced to bring an action against Tufts, in which he sought to make good his right to this half-share. The case was tried, as I have said, by four courts; but ultimately (and only a few months ago) a decision was given in his favour. The court held that the miner must divide equally with the man who advanced the "grub-stake", and thus Hollingsworth's original loan of £400 has brought him £400,000—a profit of 100,000 per cent.

You will like, I dare say, to hear a little about money. Some kind of currency is in use amongst all peoples, and all civilized nations now make use of coins. But in the early days of our history we had no coins, and all exchange was carried out by means of barter. The Phœnicians, who were the first people to practise an extensive overseas trade, exchanged goods with African races for gold-dust. The traders never saw their customers, and the deal was made without any conversation between the two parties. The sailors would land at a given point, place their wares on the ground, and then return to their ship. In the morning they would land again, and would find a heap of gold-dust beside the things. If they considered the heap big enough, they took it and sailed away. If not, they left gold-dust and goods and went back to the ship till the next morning. Then if the gold-dust had increased during the night to what they considered the right size they would take it, but if it was still the same amount they would

understand that no more would be offered. Thus a standard of value and a standard of honesty were established simultaneously. In Britain we had no gold-dust at that time, but we traded in copper, tin, amber, skins, wool, &c. When the Romans came they encouraged agriculture, and Britain became known as the granary of the north. The Romans, of course, had a coinage, but with the decline of Roman rule their influence waned and soon the coins fell into disuse. People lived largely on their own produce. Every man had his three fields: one for meadow, one for barley, and one fallow. There was, moreover, the village "waste" or common, whereon pigs and cattle could roam. The only thing which had to be bought, and that only by dwellers inland, was salt. But even for this no money was given, but hides or corn or eggs. No wages were paid, labourers being bound to work for the lord of the manor in return for their house and land.

With the growth of communication and trade, however, some system more convenient both to buyer and seller had to be instituted. A man might have a good load of wool to dispose of, but he might not happen to want several lean pigs in place of it. Again, the kings wanted money for a hundred things, but they did not want droves of oxen and baskets of hens. So taxation, trade, and coinage grew side by side. In the thirteenth century there were no less than fifteen mints in different parts of the country. This dispersed the money widely, but it also gave opportunity to the counterfeiter. The only coin made at that time was the silver penny. The penny weighed twenty-four grains (one pennyweight), and two hundred and

forty pennies made a pound. When a man wanted a halfpenny or a farthing he simply cut his penny into two or four. It was these little bits of silver that the benevolent nobles used to scatter when the crowd cried "Largess!". How tiny they must have been we realize when we learn that a silver penny was the size of our threepenny piece.

With the spread of money many of the serfs emancipated themselves. If they did not want to work for their lord on a particular day they paid him a day's wage (twopence). After the Black Death, when labourers were scarce, wages began to go up, and so more and more money circulated. You all, I hope, know your English history so well that it is unnecessary for me to mention the great upheavals, both civil and religious, which the country, and consequently trade, has suffered. I may mention, however, a petition which was presented in 1330, which pointed out that whereas "beer is one penny for three gallons", a penny was the coin of least value. It was requested that smaller coins might be struck for the petitioners' little purchases and "for works of charity". The petition was not granted, however, but by the time of Elizabeth a change was felt to be so desirable that "tokens" were in circulation. These tokens were made of lead, tin, or leather, and when they were issued by responsible persons they were very helpful to the public. Naturally the practice was abused, and bad tokens were circulated as successfully as bad money, so that they had to be abolished. The next idea was to strike brass farthings, which were so widely adopted that hardly any silver or gold circulated. This would not do, so the brass farthings

were suppressed. Immediately the tokens reappeared, and it is said that in the latter half of the seventeenth century over twenty thousand different kinds were in use. In 1672 a copper coinage of pennies, half-pennies, and farthings was instituted, and the tokens died a natural death.

Coining was at first a very clumsy business. The metal was hammered into thin strips which were cut up into square pieces. The squares were then rounded. The coin was placed between two dies, which were each struck with a hammer, this being sufficient to give the rude impression that the age required. Naturally the impressions were often crooked and incomplete, while the plain edges of the coin invited the attentions of the clipper. An improvement was introduced in the sixteenth century by the invention of a machine by a Frenchman named Brucher. This apparatus was worked by a screw, and was much more certain in its results than the hammer. It was, however, expensive to work, and it was not until 1662 that it came into exclusive use in the London Mint. The machinery employed to-day is exquisite and marvellous in construction, as we shall see.

The gold or silver arrives at the Mint in the form of ingots. It passes first into the hands of the assayer, who weighs and tests it. Ingots of gold weigh between 200 and 400 ounces (troy). Crucibles of plumbago, each holding about 1200 ounces, are used to melt the metal. The crucibles are made red-hot, and then the gold and a certain amount of copper are put in. The proportion in Great Britain is two parts of copper to twenty-two parts of pure gold. The

copper, of course, has the effect of hardening and strengthening the gold. The molten metal is poured into moulds made of iron, which vary in size according to the value of the coin to be made. The mould for sovereigns produces a bar 21 inches long, $1\frac{3}{4}$ inches broad, and $\frac{3}{8}$ inch thick. Now the bars are rolled, a process much resembling mangling, except that the rollers have hard-steel surfaces, are driven by steam, and approach one another more and more nearly as the bars grow thinner. After the rolling the bars are cut up into convenient lengths and annealed, and now are known as fillets. So perfectly do the rollers do their work that the fillets never vary in thickness more than $\frac{1}{10000}$ inch. Even that variation would be too much, so the fillet is corrected still further by the "draw-bench" in which it is passed between steel blocks. After this operation it is exactly the right thickness for making sovereigns.

The fillet now goes to the tryer, who, by means of a hand punch, cuts a trial blank from the fillet and weighs it in a balance. If this blank is of correct weight the fillet is passed, but if not, it is sent back again to be re-melted. The fillet we are watching is quite correct, and it goes on to the punching-machine to be made into blanks. The fillet is put on a carrier and pierced by two short steel plungers. Then the carrier jerks forward, and the plungers plunge again. The waste pieces from the fillet, called *scissel*, go back to the melting-pot. Next to the punching-machine is another to which the blanks immediately travel. This is a very ingenious machine. A workman stands beside it gently shooting little piles of blanks into a funnel, from which they pass, one by

one, between two grooves. One groove is in a fixed block, the other in a revolving disk. By pressing the blanks into these grooves their edges are raised, and they are reduced to a uniform size. They drop down a shoot and into a drawer when finished, and then a number of strange things happens to them. First, they are packed into little iron boxes which fasten on to an endless chain. When all the boxes are full, the chain starts on a slow and solemn journey through a fierce furnace. By this means the blanks are annealed. On coming out of the little boxes the blanks are dipped into hot dilute sulphuric acid, then washed with water, and lastly dried in hot saw-dust. Now they are all ready for stamping.

I have mentioned before the screw-stamping presses which marked the first development in minting machinery. These remained in use until 1882, when lever presses were erected. In these presses the blank is placed on the lower die, which is fixed, and a steel collar milled on the inside rises round it. Then the upper die descends with full force, and the soft coin receives the impression of the three parts. Immediately the die rises again, the collar falls back and the coin passes to one side, leaving the die clear for the next blank. A careful operator strikes ninety coins a minute.

Now the coins are finished, but they are not yet ready to venture out into the great world. First, they are carefully examined and are then weighed in wonderful balances introduced by William Cotton in 1844. These instruments can weigh twenty-three coins in a minute and pass each one into its proper compartment. There are three compartments: num-

ber one being for coins that are too heavy, number two for coins that are too light, and number three for those that are within the legal limits. The contents of numbers one and two go back to the melting-pot. The contents of number three are rung on an anvil and sample coins are carefully assayed. The last episodes in the minting of coins are performed by a wonderful machine which once more weighs and tests them, counts them, and drops them into bags. As a rule these bags go straight to the Bank of England.

The minting of silver and copper coins is practically the same as that of gold. The alloy, of course, is different, silver coins being made of two hundred and twenty-two parts of silver to eighteeen of copper, and copper of ninety-five parts of copper, four of tin, and one of zinc.

CHAPTER X

Precious Stones

WHAT is a precious stone?

I have been thinking hard for a long time, and the only answer I can find to that question is "A stone that is precious". Not very illuminating, is it? The fact is, the question opens such a vast field of thought that no one answer will settle the matter. We may say that a precious stone is a beautiful stone. Very well, then, common spar and white quartz are precious stones. No? Precious stones are hard and durable, but nobody would pay anything for a bit of flint. Precious stones are rare. So are the green pebbles you sometimes find on the beach, but no jeweller fills his windows with them. Besides, if we were to examine the books of jewellers for the last two hundred years or so, we should find extraordinary variations in the prices and values of stones. Sometimes we should find huge prices paid for emeralds, sometimes for opals, sometimes for aquamarines.

The quality of preciousness, then, is unlike mercy inasmuch as it *is* strained, and strained very finely indeed. It is a quality not of heaven but of earth. Beauty, durability, rarity, all are essential, but the beauty is governed by two intangible and inconstant forces—the forces of Fashion and Taste. Fashion

decrees what stone shall occupy the principal place: taste is responsible for changes in setting and workmanship. Years ago, for instance, rubies and opals were commonly used together. Now we should consider that a hideous combination, and one that was useless since neither stone enhances the other. To-day, taste places diamonds beside opals.

Strange and ridiculous though it may seem, another factor in raising the price of a stone is the name. "Green garnets" do not appeal to anyone, but "Uralian Emeralds" command a relatively high price, while the ordinary red garnet is an expensive luxury when it is called a "Cape Ruby". This attitude of mind is best described by the vulgar substantive "swank", and if I were writing a book upon shopping generally I should wax eloquent upon it. Why is it that no furrier could do any business if he honestly labelled his goods "rabbit" and "goat"? Why does not the jam manufacturer offer you "Finest Turnip Jam, Flavoured Strawberry"? Why does not the draper tell his customers that his famous cheap silk is made of wood? How should we be poorer, or hungrier, if we resolutely called things by their right names? However, I am wandering from my subject.

Half an hour spent intelligently in the South Kensington Museum will teach you more about the appearance of precious stones than three days of reading on the subject, so with your kind permission we will just step round there and have a look at the Townshend Collection. According to Professor A. H. Church, the jewels in this collection may be divided into twenty-two families, as follows: Diamond, Corundum, Spinel, Turquoise, Topaz, Tourmaline,

Garnet, Peridot, Beryl, Chrysoberyl, Liscon, Opal, Quartz, Lapis Lazuli, Iolite or Dichroite, Crocidolite, Felspar, Apophyllite, Pyrites, Lumachella or fire marble, Malachite, Pearl. I have not the space to tell you about all these stones, and many of them are rarely met with out of museums. One family, the pearl, being of animal origin, does not enter into this book at all. Moreover, by studying this or a similar collection we can learn what an important part the workman plays in the production of a beautiful gem. The different methods of cutting stones can be compared, while the advantages of artistic setting need no pointing out. The turquoise, a dull, uninteresting stone in a commonplace setting, becomes a thing of beauty when surrounded by diamonds (Number 1263); while Number 1262, "bordered with 14 rose-cut diamonds, each in a floret, and with an outer oval of 14 brilliant-cut diamonds, 3 brilliants on each shoulder of the open-work ring",[1] is a jewel for a queen.

We cannot help observing, however, that precious gems have a wondrous beauty of their own. Most of this is due to the workman, for the stone in its raw state is dull and insignificant. But its beauties were latent, waiting for the skilled hand to develop them, and obviously the stone retains the credit of its own qualities. The durability and rarity of the stones we call precious need no qualification. Their beauty is a more elusive matter, hard to define and resting upon certain natural laws. Broadly speaking, the beauty of clear stones such as the diamond and ruby depends on their power to refract and disperse light.

[1] *Precious Stones*, by A. H. Church.

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THE BEGINNING OF DIAMOND-MINING

The Robert Victor Mine, showing the great pipe of "blue ground" in which the diamonds are found embedded. The blue ground is shattered by explosives and carried to the surface. After crushing and various processes of washing with water the light soil is washed away and the heavier material containing the diamonds is left.

The dispersion of light produces what we call the "fire" of the diamond. The diamond, indeed, possesses greater powers of refraction and dispersion, as well as greater hardness, than any other stone. No doubt these are the reasons why we always consider the diamond as the most precious of all stones. It can stand a lot of rough wear, though a fall or a sharp blow may break it, and it has the additional advantage of being always in fashion. Hard-headed business men regard diamonds as a good investment, and they are always a "safe" present for a lady, as they suit all complexions. Pearls do not, for though they enhance the charms of the young and lovely they are somewhat trying to those who are neither. But there is absolutely no necessity for me to go into delicate and abstruse details of that kind. The difference in hardness of the best-known precious stones is as follows:—

Diamond	10.0
Sapphire	9.0
Ruby	8.8
Topaz	8.0
Aquamarine	8.0
Emerald	7.8
Tourmaline	7.5
Amethyst	7.0
Jade	6.5
Peridot	6.3
Moonstone	6.3
Green garnet	6.0
Turquoise	6.0
Opal	6.0
Lapis Lazuli	5.2

Not only is this table useful as showing which stones are likely to wear best, but the hardness test is used to distinguish stones from one another, and real stones from imitations. A succession of mineral substances of varying hardness is used to make the test, and the place in the scale of the object under examination is discovered easily. Thus, a stone which will scratch a tourmaline but which is scratched by an aquamarine falls into the place of an emerald. The diamond cannot be scratched by any other gem, the sapphire only by the diamond, the ruby by the sapphire and diamond, and so on. The transparency of stones also is reckoned among their essential points, and is divided into several degrees:

1. Transparent, when objects may be seen clearly.
2. Semi-transparent, when objects may be seen faintly.
3. Translucent, allowing the passage of light.
4. Sub-translucent, when light passes through very thin splinters only.
5. Opaque, when no light passes.

Another prominent quality of a stone is its lustre. There are seven different kinds of lustre, of which the most noteworthy are: adamantine, which is applied to the diamond; vitreous, to the emerald; waxy, to the turquoise. Metallic and adamantine lustres belong to stones having the highest refractive powers.

The name "diamond" is derived from "adamant", from the Greek word "adamos". This word *adamas*, originally meaning "invincible", was applied by Theophrastus to the emery-stone of Naxos, which was the hardest crystalline gem then known. From that it became the designation of any "hardest" metal.

The Latin writers, however, confused matters by connecting the word with *adamare*, "to have an attraction for", and *lapidum adamantem* represented the lodestone or magnet. Scientists of the Middle Ages used "adamant" as a synonym for "diamond", but it was not until the end of the seventeenth century that the meaning of "magnet" was lost.

We know that diamonds are composed of pure carbon. In this they stand alone, since no other precious stone consists of carbon. The purer the carbon the better the diamond; but just how the stone has been formed we cannot tell. One thing we know is that ages of enormous pressure have been needed to evolve it from a tree trunk or a bit of soft mud, and it is the necessity of this pressure which proved the greatest obstacle to the making of artificial diamonds. The diamond is of extraordinarily-hard substance, or, in scientific parlance, the cohesion of its particles is such that it can be ground to an infinitesimal point. An instrument has been made to control a pen of which the "nib" is a diamond ground to a point *a million times finer than that of a pin!* With this instrument the Lord's Prayer has been written out in full in $\frac{1}{366000}$ of an inch. A better idea of the tiny nature of this writing is obtained by the fact, stated by a president of the Microscopical Society, that the whole of the Bible could be written twenty-two times in 1 square inch! Naturally a very powerful microscope is needed to read this writing; so powerful is it that, if it were possible to put your young brother under it, he would look ten times taller than the Monument. Nobody, of course, wants to have the Bible written out twenty-two times in a

square inch, but biologists and microscopists generally do want to make numbers and letters on specimens which are hardly visible to the naked eye. Descriptive titles to microscopic slides also have to be written in the minutest letters, which a hundred years with Jackson's upright penmanship would never teach us to produce.

India used to be almost the only diamond-producing country of the world. Now its output is insignificant, that of the diamond mines of South Africa being so tremendous as to dwarf all others. Yet the diamonds of Brazil, Borneo, and Australia are not to be despised, and the Koh-i-noor, Great Mogul, and Orloff are all Indian stones of great size and romantic history. The Koh-i-noor is reputed to be four thousand years old, but its story begins in the fourteenth century A.D., when it was the property of the Rajah of Malwa. The Sultans of Delhi conquered Malwa and appropriated the jewel, but by the fortunes of war it again changed hands, this time falling to Mahommed Shah. Mahommed eventually was defeated by Nadir Shah, but concealed the diamond in his turban. Very unwisely, as it turned out, he told one of his wives what he had done, and she, having a spite against him, betrayed the story of the diamond and its hiding-place to Nadir. Nadir then ordered a banquet to be prepared, and invited Mahommed, with whom he swore eternal love and friendship, and various other things. At the close of the feast Nadir suggested that they must celebrate their union in some remarkable way, and after some cogitation declared that they would change turbans. Without waiting for Mahommed to reply, Nadir snatched the turban off his head and

banged his own down in its place. When Nadir unrolled his new turban, he exclaimed: "Koh-i-noor" (mountain of light), by which name it has been known ever since. After various further adventures the stone was lodged in the treasury at Lahore, and became the property of the British on the annexation of the Punjab. It was immediately presented to Queen Victoria, and was delivered into her hands on 3rd June, 1850. It was exhibited in the Great Exhibition of 1851. Its weight was then $186\frac{1}{16}$ carats, and since its form was not altogether satisfactory, it was decided to recut it. By this process, which employed eleven men for thirty-eight days, its weight was reduced by 80 carats. Authorities do not agree as to the wisdom of the step, but the general opinion is that it is now too shallow to display much fire.

The diamond mines of South Africa might have remained unknown for a still longer time but for the fact that one day a little boy, being in want of something to do, set himself to collect pebbles. Amongst his trophies was one stone so bright that his mother noticed it, and showed it as a curiosity to a neighbour. By his advice the stone was tested, and proved to be a diamond. This was the first one to be found in South Africa, and speculators immediately rushed to the spot.

The excitement was greatly increased by another curious accident. A farmer in the district, having occasion to knock a hole in one of the mud walls of his house, was amazed to find diamonds embedded in the daub, which had been taken from a pond near by. Needless to say, the farmer left his farm to look after itself, and devoted his energies

entirely to digging over his ground in the hope of finding more diamonds. Nor was he disappointed. In a very short time he had marked out the farm into claims of twenty square feet each, which he offered to prospectors for £50. So eagerly were they applied for that the price rapidly rose, until as much as £50,000 was paid for ten square feet. In these mines, which are now known as Du Toits pan, the famous Stewart diamond was found in 1872. It weighed 288⅜ carats, and was the first great diamond to be found in South Africa; but it sinks into insignificance beside the stone found at Jagersfontein in 1893 weighing 971 carats, and the Cullinan diamond, taken from the Johannesburg Premier mine in 1905 and weighing 3032 carats.

These good old days are gone, never to return to Africa at any rate. Possibly in some future time a new diamond country will be discovered, and poor speculators will reap a fortune by finding a single stone. The romance has gone from Africa, and the fields that used to be a veritable Tom Tiddler's ground are now covered with machines and riddled with mines.

Capitalists control the whole country: the daily output of the mines is regulated carefully in accordance with the state of the money market: everything is cut and dried and carried out according to rule. Yet the business of diamond getting by machinery is so wonderful that we cannot deny its fascination. It is a triumph of the scientist, whereas the old way was often the triumph of chance. We may feel envy but no respect for the man who, a failure and unskilled, drifting to the diamond fields

as a last resort, managed to pick up a goodly sum. We can feel nothing but admiration and boundless respect for the men who have designed and constructed the extraordinary machines which do the work of thousands of men. In 1911 South Africa exported diamonds to the value of £8,281,907, or one-seventh of its entire export trade—£8,000,000 for the delight and vanity of buyers—and this does not represent the whole of the world's diamond trade. Dust and fragments of stones are used to make lapidaries' wheels and other instruments, but the business in dust forms an infinitesimal part of the trade.

How, then, do the capitalists conduct this trade? Partly by machinery, partly by hand labour, partly by natural forces. If we could transport ourselves bodily to South Africa we should see all the processes at work. We cannot do that, but you must give me your minds and let me impress upon them a succession of episodes in the life of a diamond.

In some cases the stones are found in alluvial soil, and then the method of getting them is much the same as that employed for getting alluvial gold. You read all about that in the last chapter, that is, unless you have been been skipping. Anyhow, I am not going all over it again. The greater number of diamonds, however, are obtained by ordinary mining processes. The stones, you must know, are found in what is called "blue ground", a very heavy soil of a bluish colour which occurs in "breccias" or pipe-like formations. Shafts are sunk often to a great depth below the surface. All the machinery of modern mining is called upon to hoist the blue ground into

the sunlight. Once arrived at the top, the skips immediately empty themselves into trucks which are promptly drawn away by an endless wire-rope to the open veld. Here Man gives place to Nature, for he knows that she can do the next stage in the proceedings better than he can. Vast spaces of the veld are covered with a thin layer of blue ground, and for a whole year the sun shines upon it, the rain rains upon it, and the winds blow it about till it becomes soft and friable as chalk. These spaces are called disintegrating floors, and besides being surrounded by fences of barbed wire, they are guarded day and night by armed sentries. The only artificial treatment the soil ever suffers while it is on the floor is that sometimes it is turned over by a steam plough. As a general rule it is left entirely to itself. When it is ready for other treatment it is loaded on to trucks which run up to the top of a little hill. Here the trucks tip up and the soil falls down into the washing-pans.

A fierce kind of washing—much worse than steam laundries! I do not think your shirts would last long if you were to drop them in. Round and round go the pans, crunching and grinding with their mighty teeth. How the noise beats upon your head, and how the slender scaffolding on which you stand trembles and shivers! When one pan thinks it has done enough it shoots the soil on to the next and yawns for a fresh supply for its own tireless jaws. Finally all the soil is washed away, and the contents of the last pan are gravel and diamonds. A hundred trucks went up the hill, but only one comes down. This truck runs along till it comes to a machine whose

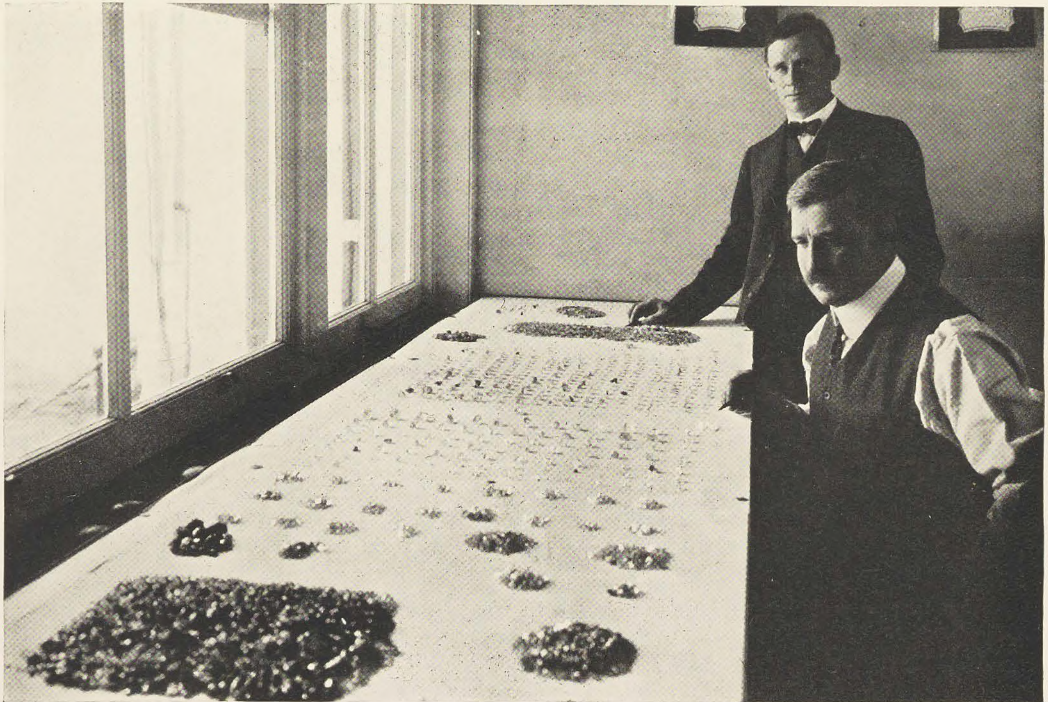
brother we have met before. This machine is the "pulsator", and he is own brother to the pulsator which separates gold from gravel. Diamonds, like gold, are heavier than the pebbles amongst which they are found. The truck pours its contents into a hopper, whence they fall upon an endless band. This band is a queer thing. It not only carries the stones along but it also sorts them out according to size. Then down they go into troughs, and at the same moment a stream of water flows in. Now the pulse makes itself felt, and water and stones go jerking along the trough. With every jerk the heavy stones are falling to the bottom. There they fall through a grating, while the light, worthless stones are washed away overhead.

Now it does not follow that all these heavier stones are diamonds, and I do not suppose you will guess how a further separation is effected. It is by means of grease. The stones pass on to a thickly-greased slab and are carried over it by a stream of water. The diamonds are not carried far; they stick to the slab. However, in case any small ones should be washed over, the business is done again on a second slab, and even then it is thought necessary to employ Kafirs to look over the remains. What happens, however, to the stones left in the grease? It would be a long, laborious business to take them all out by hand, and time- and labour-saving devices are the *desideratum* of the capitalist. Grease, diamonds, and any very heavy pebbles that may have intruded are all scraped and put into a pot. The pot is swung into a huge cauldron of boiling water and twirled round and round until all the grease is washed away.

Now we have a heap of fascinating stones, not, indeed, beautiful to look at as yet, but possessing a future of triumph and splendour. Here and there the expert eye will detect a common pebble, and the stones are now carried away to be sorted finally.

Here in a quiet room sit many Kafirs at long tables. Only one white man is with them, and he might be described as "He of the watchful eyes". All day he watches, watches that the Kafirs do not give way to temptation and appropriate the precious stones. The sunlight helps him, for the walls of the room are mostly window, through which the brilliant southern sun streams untiringly. The Kafirs have no chance to steal, and if they did they would find it difficult to dispose of their booty. In the old days it was comparatively easy both to steal and to reap the profits. The Kafirs were subjected to an examination before leaving work, but a little thing like that did not deter them from carrying away diamonds. They had innumerable tricks and ruses. Sometimes they would cut a hole in their legs or some other fleshy part, put the stone in and close down the flap of skin. If they had no time or opportunity to perform such a delicate operation they would simply swallow the stones. But nowadays the law is too strong for them. "I.D.B."—illicit diamond buying—is a heinous crime, punishable by years of imprisonment both for the buyer and the seller. Vulgarly speaking, "the game is not good enough".

The value of a diamond depends more upon its purity than its size. The result is arrived at by multiplying the value of the first carat by the square of the weight. But pure diamonds are cheap and



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THE END OF DIAMOND-MINING

Sorting £100,000 worth of diamonds at Jagersfontein. In the sorting-room the useless material is discarded and the diamonds are grouped according to their colour and shape. In 1911 South Africa exported diamonds to the value of over £8,000,000.

common in comparison with pure rubies. The ruby is a member of the corundum family. The characteristic element of corundum, and also of spinel, turquoise, topaz, tourmaline, and garnet, is aluminium. The stones individually named corundum in the Townshend Collection are coarse varieties of the mineral, the finest specimens being known as rubies and sapphires. Spinel is a mineral closely allied to corundum. Many so-called rubies are really only fine spinels. Oriental rubies of perfect colour are very scarce, and are rarely more than eight carats in weight. Those most esteemed have the colour of pigeon's blood, and come from Mogok, north of Mandalay. Sometimes they occur in crystalline limestone and sometimes in alluvial deposits. Stones of inferior colour are found in many parts of the world and are distinguished by various names. Spinel ruby is of a deep carmine-red; Balas ruby is rose-red; varying shades of orange-red are known as Rubicelle and Vermeil, while the Alamandine ruby has a violet tinge. Marco Polo mentions that "in this country (Balashan) are found the precious stones called Balass rubies, of fine quality and great value, so called from the name of the province. They are embedded in the high mountains, but are searched for only in one, named Sikinan." The same traveller also tells a story of the king of the island of Zeilau. "The island," he says, "produces more beautiful and valuable rubies than are found in any other part of the world, and likewise sapphires, topazes, amethysts, garnets, and many other precious and costly stones. The king is reported to possess the grandest ruby that ever was seen, being a span in length and the

thickness of a man's arm, brilliant beyond description, and without a single flaw. It has the appearance of a glowing fire, and upon the whole so valuable that no estimation can be made of its worth in money. The grand khan, Kublaï, sent ambassadors to this monarch with a request that he would yield to him possession of this ruby, in return for which he should receive the value of a city. The answer he made was to this effect: that he would not sell it for all the treasure of the universe; nor could he on any terms suffer it to go out of his dominions, being a jewel handed down to him by his predecessors on the throne. The grand khan therefore failed to acquire it."

This sounds like a fairy tale, and the editor of the "Travels" in his note leads us to presume that it is one. He says: "If this extraordinary stone had any real existence, it may have been a lump of coloured crystal; but it is not uncommon with eastern princes, in the preambles of their letters and warrants, to boast the possession of imaginary and improbable curiosities; and, in this instance, the fallacy of the pretension will account for the king's rejecting the magnificent terms held out for the purchase of it by the Emperor of China."

The sapphire is practically a blue ruby, or the ruby is a red sapphire, whichever you like better. The value of the sapphire, however, depends solely on its purity, and does not increase in proportion to its size, as does that of the ruby and diamond. Varieties of sapphire and of garnet and topaz are all called sometimes by the name Hyacinth. It is probable that the sapphirus of the Bible is hyacinth, not the true sapphire.

The emerald belongs to another class of gems, the Beryl family. Common beryl in many respects resembles the emerald, but its colour is weak, being yellowish green or blue. Precious beryl is the stone known as aquamarine, a very beautiful gem, but not so valuable as the emerald. The emerald is a stone of great antiquity, and many have been found in the ruins of Thebes. They were used not only for adornment but also for making eye-glasses. Nero, we know, was short-sighted, and it is supposed that the glass which he used to watch the gladiator fights was made of emerald. No doubt the stones came from the Urals and other parts of Europe, or from Upper Egypt. The finest stones we now get are from Columbia.

Amethysts are popular on account of their pretty colour; but, being found abundantly, they are not of any great value. They occur in many parts of Europe, including Scotland, where the stone abounds; but the best amethysts come from India, Ceylon, and Brazil. The name is derived from the Greek word *amethystos—a*, not, and *methy-ein*, to be drunken. The Greeks believed that amethyst had the power of warding off drunkenness, and for this reason they used to make their drinking-cups of it. Persons who had an unfortunate habit of taking more strong drink than they could deal with conveniently used to wear a piece of amethyst round their necks as a charm, but I do not suppose it had the desired effect.

Amethyst is a form of quartz, and has a number of brothers and sisters. Among these we may see in the Townshend collection cairngorm, plasma, chrysoprase, chalcedony, agate, and onyx. The characteristic element of quartz is silicon, and in this respect

the opal resembles it. Silicon is more abundant in the globe than any other solid, and if we were to isolate it it would appear as a dark-brown powder. It never occurs in nature except in combination with oxygen. The chief point of difference between opal and quartz is that opals contain a certain amount of water, and they are of crystalline structure. The opal is very easily broken, and it is partly on that account that it is never faceted, but chiefly because it displays much greater beauties when polished *en cabochon*. The wonderful colours of the opal are due to tiny fissures in its depths, which refract the light. The range of colours exhibited by a fine opal is unequalled by any other stone, and it is no doubt this property which has led to its being regarded as a stone of evil influence. Nevertheless the opal is one of the stones which enjoy a fashionable season at intervals. The best specimens come from Hungary, and are neither so milky as to be opaque nor too transparent, as are many of the Queensland and Honduras stones, but of an intermediate condition.

Probably we should not recognize any of these stones if we were to pick them up in the rough state. Between the mine and the jeweller's window lies a series of operations which transforms the rough pebble into a glittering gem. Art and science have their work to do before the finest specimen is fit to appear on its little velvet mount beneath the pitiless electric light. The shaping, cutting, and polishing of a stone are long and intricate processes. There are certain hard-and-fast rules which must be followed, but individual stones all require special treatment. They must be humoured and approached with tact in order

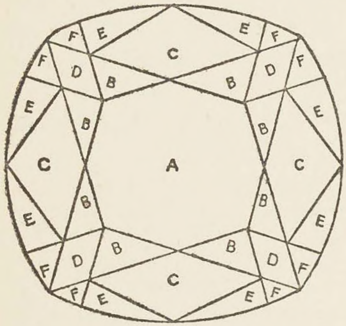
to bring out their best points. Moreover, the processes give a certain amount of hardness to the stones, rendering them less liable to fracture.

The apparatus used for polishing is quite simple, the success of the process depending almost entirely on the skill of the operator. I have already said that diamonds fracture easily from a blow—a circumstance that puts quite out of court the good old story that the ancients tested their diamonds by putting them on an anvil and striking them with a hammer. The gems are first split and then roughly cut to shape with rough, imperfect stones. They are afterwards polished by grinding them on rapidly-revolving metal disks covered with diamond dust and oil.

There are eight main forms into which precious stones may be cut, falling naturally into two groups. First, those having plane surfaces, such as brilliant cut, step or trap cut, table cut, rose cut. Second, those having curved surfaces, such as single cabochon, double cabochon, hollowed cabochon, and tallow top. Changing fashions modify these forms slightly from time to time, but the general idea remains the same. While the brilliant cut is best suited to diamonds, many-coloured stones show to greatest advantage when trap cut. The rose cut is the most ancient cut, and is less in use nowadays. Translucent and opaque stones are most frequently cut *en cabochon*, though clear stones are sometimes subjected to it.

The brilliant cut is a very complex form. It requires fifty-eight facets to be complete, and this number may be increased to meet the exigencies of prevailing taste. Recently sixty-six facets have been popular. These facets are of definite arrangement

and proportions, as a glance at the diagram will show. Fig. 1 shows the "crown" or upper part of the brilliant, fig. 2 the "pavilion" or under part. The crown consists of A, the table; B, eight star facets; C, four templets or bezils; D, four quoins or lozenges; E, eight cross or skew facets; F, eight skill facets—making a total of thirty-three. The pavilion is less complicated, having the culet or collet; four

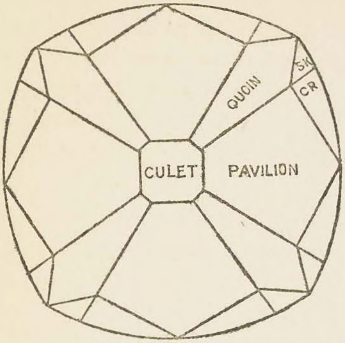


1 Table.		
8 Star facets.		
4 Templets or bezils.		
4 Quoins or lozenges.	=	"The Crown" or upper part of the brilliant.
8 Cross or skew facets.		
8 Skill facets.		
33		

Fig. 1

pavilion facets; four quoins; eight cross facets; and eight skill facets. Between the crown and the pavilion is the "girdle". This is concealed, as a rule, by the setting, and needs to be of exactly the right thickness. If it be too thin, it is likely to break or chip in the mounting; if it be too thick, it detracts from the beauty and brilliancy of the stone. The crown should be one-third of the thickness of the stone, the pavilion being two-thirds. The proportions of the facets are all fixed and decided, and any divergence from the accepted measurements is attended with inferior results. The Koh-i-noor, as I

said before, is too thin to display much fire; that is, it is too broad in proportion to its depth. The Regent,



1 Cullet or collet.		
4 Pavilion Facets.		
4 Quoins.	=	"The Pavilion" or base, or under part of the brilliant.
8 Cross facets.		
8 Skill facets.		
—		
25		

Fig. 2

on the other hand, is too deep for its width, and a dulling of the stone has resulted.

Naturally coloured stones need different treatment. As a rule, the step or trap cut is used for them, this

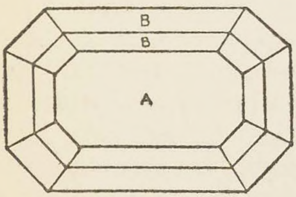


Fig. 3

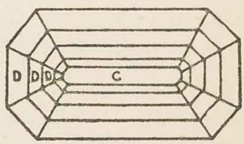


Fig. 4

being a process which admits of greater variation than the brilliant. The proportions are not adhered to strictly, the workman being allowed largely to use his own discretion. The step cut (fig. 3) consists of A, the table; B, two or more sloping step facets in the crown: and the base (fig. 4) C, the culet; and D,

three or more zones of steps. It is the steps which give light and brilliance to the stone; and if the table be too broad the stone loses its effect.

When garnets are cabochon cut, they are known as carbuncles. The garnet is the only clear stone frequently cut in this way. The turquoise is the most common example of cabochon (fig. 5). The opal is generally cut in the form known as tallow top (fig. 6).

I must tell you a little about artificial stones. There are, of course, two kinds of artificial stones; those

Fig. 5

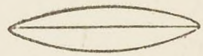


Fig. 6

that are actually the same in composition as real stones and those that are simply crude imitations. The first kind is the more interesting, I think, since the making of them has been achieved after numberless experiments by men of science. Yet man can never succeed in exactly imitating nature. Man's resources are finite, even though he have the best-equipped laboratory in the world, for man has only one short lifetime in which to work. He may leave the results of his investigations and experiments to posterity, and some other may take up the work after him; but there is a gap, a want of cohesion in the methods of working. When Darwin died his disciples went on with his work, and came to many startling conclusions; but we cannot suppose that they were identical with conclusions Darwin himself would have

reached had his life been prolonged. No two men theorize or experiment in precisely the same way. But there is no death in Nature. Her methods are the same, age after age, and she has eternity to work in. All the forces of the world are at her disposal. The rush of rivers, the grinding weight of glaciers, the rage of the volcano, the quiet erosion of a thousand years of rain, all are hers. How, then, can man, with his paltry threescore years and ten, his feeble furnaces and his featherweight pressures, hope to compete with her? He could not, in the manufacture of gems, but for one point. This is the fact that our so-called precious stones are not naturally the product of great heat. The accepted theory of their development is that they have been formed by long-continued pressure, probably under water. Now the chemist cannot provide long-continued pressure, but in this instance he can dispense with it. He can make great heat—great, that is, from a human point of view, not in comparison with Nature's furnaces—take its place. The analytical chemist discovers the constituents of a stone. It remains for the synthetical chemist to put them together. The instrument he uses for this purpose is known as the oxyhydrogen blowpipe.

You are all familiar with limelight, I expect—that dead white light which sometimes produces such ghostly effects on a darkened stage, but which, passing through coloured shutters, represents the dewy eve or shining morn, moonlight or sunlight, with equal fidelity or the want of it. The "limelight" man is an important person in every theatre; and if he were to go on strike I am afraid the brightest pantomime would lose half its sparkle. Well, the

limelight man does his work with an application of the blowpipe. The apparatus consists, roughly speaking, of a narrow tube through which a flame is blown against a block of pure lime. The lime becomes incandescent, and gives off a blinding light. The heat of the flame and consequent strength of the light depend upon the kind of gas used. Thus oxygen blown through a spirit flame gives a light of 150 candle-power. Oxygen under pressure and coal-gas give 200 candle-power; while warm oxygen, saturated with benzoline—a sufficiently dangerous combination, one would think—gives a light equal to 1350 candles. But the blowpipe of the chemist has, of course, nothing to do with limelight. Its object is to produce intense heat, not intense light. Suppose he wants to make a ruby. The necessary ingredients are pure alumina and some colouring matter, say chromium oxide. These substances will fuse if heated sufficiently. An ordinary flame is by no means hot enough, so the chemist has recourse to the blowpipe. He will use a combination of oxygen and hydrogen for his flame. By means of the pipe he then blows air into the flame, thus causing a perfect combustion of the gas. This reduces the light of the flame, but greatly increases its heating powers.

The alumina and chromium oxide having fused, the result appears in the form of a ruby glass; but if it is allowed to cool very slowly it will crystallize in exactly the same way as natural corundum. Artificial spinel has been made by combining alumina and magnesia, and after it has been cut and polished it is impossible to detect the natural from the artificial stone. There are other methods of making gems, one of which is

that of combining the constituents in a state of vapour. Chrysoberyl has been formed by subjecting fluoride of aluminium and fluoride of glucinum to great heat in a lime crucible. Science is progressing constantly with huge strides, and there is little doubt that the synthetic production of anything is simply a matter of time.

There is nothing clever or dignified in the mere imitation of precious stones. Such imitations frequently are made from dishonest motives, and when not actually dishonest, the makers pander to a desire for display, a love of finery, no matter how cheap, that is, if nothing else, foolish. Very often it is downright harmful, as when girls squander money on a flashy "ornament" that they ought to be saving or laying out on strong boots or a warm coat. Of course there is no deception in offering a brooch set with coloured-glass "stones" for sale at a low price. Nobody would expect to buy sapphires or rubies for two or three shillings. The damage such trade does is moral rather than actual. But undoubtedly it is dishonest to sell as diamonds stones that really are nothing but white sapphires. Such frauds are easily detected by the hardness test, but the average buyer of jewellery knows nothing of such things. Imitation stones are made frequently of a substance known as "strass". This is a very soft material, and readily scratches with a file or even with a piece of glass. Moreover, it tarnishes in impure air, the lead it contains turning brown. But a number of tricks are used to avoid detection. For instance, a stone presumably a sapphire, is offered for sale. Should the buyer attempt such a thing, he would find the stone

would scratch a ruby, and could be scratched by a diamond. It must, therefore be a sapphire. So it is, down to a point—the point, that is, of the girdle. A colourless sapphire is used for the crown, but the sapphire ends at the girdle, and a layer of blue glass forms the base. This kind of fraud is called a doublet. The triplet has been devised to take in people who have heard of the doublet, and might be tempted to try the base as well as the crown of the stone. The triplet consists of a pale sapphire crown and base and a girdle—this being hidden by the mount—of blue glass. The glass gives colour and richness to what is really a very inferior stone. If a doublet or triplet be boiled in water or put into a small quantity of chloroform it will drop to pieces.

Imitation pearls are made by our old friend the glass-blower. The glass is slightly opalescent, and is coated on the inside with a preparation called Essence d'Orient, which is made from the scales of a fish. When the essence is quite dry the bead is filled with wax.

CHAPTER XI

Rarer Treasures of the Earth[1]

CHEMISTRY teaches us that the solid earth upon which we live, the waters that cover so large a part of its surface, all the substances that are dissolved or that float about in these waters, and the air that forms the outer wrapping of our world, are made up of about eighty or ninety really different kinds of material. Each of them is known as an element. Some of these elements occur in such very large quantities that 99 per cent or more of the whole earth is composed of about a dozen of them. Others, again, are found only in very small amounts and in very few places. Some of these rare elements have, as far as we know, little or nothing to make them interesting except the fact that they are rare. But amongst the number there are many which, for one reason or another, are well worth more attention than they generally get, and this chapter is to be devoted to a talk about those of them that are useful or that have an interesting story of some kind.

The chemists of bygone days were acquainted with seven substances to which they gave the name of metals. These were gold, silver, mercury, copper,

[1] I have to express my indebtedness to Mr. Hubert Painter, B.Sc., F.C.S., who, with the greatest good nature, supplied me with the material for this chapter.—C. H.

iron, tin, and lead. As knowledge increased and fresh elements were discovered it was found that most of the new ones were entitled to the name of metal because they had so many points of likeness to the members of the original group of seven. A really representative metal is generally heavy, and can always be polished so as to give a shining appearance which, in the old days, was called the "metallic splendour". It allows heat and electricity to pass easily through it, and it can often be made into thin wire and beaten out into sheets or leaves. Any element which possesses most of these properties is considered to have passed its examination, and is admitted into the Ancient and Honourable Company of the Metals. Only a very few of the metals are found in the earth in the "free state", that is, as metals. The great majority, as we have seen, occur combined with other elements, such as oxygen, sulphur, and so on, and, like the princes of fairy tales, are in disguise. Who would have thought, for example, that the bright, silvery metal aluminium could lurk as it does in dull, unsightly clays? Yet such is the case, and many other metals are extracted from stony-looking minerals, which give in their appearance little or no promise of their precious contents. Gold is one of the few metals which are found in lumps and grains amongst sands and gravels and in glistening particles in hard, flinty rocks.

There are a few other metals which are like gold in this respect, and form with it and silver a little company of "noble metals", so called because they never rust nor corrode in air or moisture, as do those belonging to the common herd of "base metals".

In this aristocratic band *platinum* holds a high place. This precious substance was discovered in South America about the year 1730 and soon excited great interest. White like silver, it is more like gold in that it does not dissolve in nitric acid; and for a long time no furnace hot enough to melt it could be made. Soon, however, means of melting it were found, and it began to be made into wire and thin sheets and used for various purposes. Search was made for it in other parts of the world, and a little of it has been found in quite a number of places. At present the mines in the Ural Mountains yield about 95 per cent of the 6 or 7 tons which come into the market each year. The uses of platinum are so many, the demand so great and the supply so small that instead of getting cheaper it is much dearer now than it was a hundred years ago. Then it could be bought for 16*s*. an ounce; to-day one would have to give more than £10. The chemist cannot get on without it in his analyses, the electrician wants it, the photographer, the dentist, and the jeweller all compete with each other for the all-too-small annual supply, and so the price goes mounting up and up. In or about 1877 a gang of coiners issued some false sovereigns made of gold "adulterated" with platinum. Now the latter metal is worth three or four times its weight in gold, and one of those false coins would be much more valuable than a real sovereign.

The platinum found in Russia contains small proportions of several other metals which are, so to speak, cousins of platinum and have properties somewhat like those of their better-known relative. One

of these is *iridium*, which means "rainbow metal". This name was given to it because, although white and silver-like itself, its chemical compounds are of various colours. This metal is very heavy, exceedingly hard, and most difficult to melt. It is used to tip the gold nibs of fountain-pens, but its chief use is in alloying platinum. One part of iridium to nine of platinum gives a mixed metal or alloy used in making pyrometers (a sort of thermometer used in furnaces), for some electrical instruments, for standard weights and various other purposes. *Osmium*, which means "smelling metal", is of all known substances the heaviest, and is even more difficult to melt than iridium. Osrid, an alloy of the two, is better than pure iridium for tipping pens, and is used for the bearings of the best mariners' compasses and chronometers. Although so difficult to melt, when it is heated very strongly in air it slowly forms a vapour of powerful and disagreeable smell which is most dangerous to breathe and very injurious to the eyes. The chemist, Deville, who first made osmium, was rendered temporarily blind from this cause. The explorer of unknown countries runs risks from savages and wild animals, or may fall a victim to the bite of a venomous snake or to the fever-laden mists of the swamp: the work of the pioneer of chemical science studying the properties of unknown substances in his own laboratory is not without its perils. The possibility of the sudden explosion or the escape of poisonous gas is never absent; and disfigurement, disablement, or even death, may come when least expected.

Besides the metals already mentioned there are

others which rank as noble. One of these, *rhodium*, the "rose metal", owes its name to the red colour of its salts. It is too scarce to be much used, but it is now possible to buy crucibles and other apparatus made of it, although its price is naturally very high. It looks like aluminium, is a little heavier than silver, but its melting-point is so high and its power of resisting acids so great that it could often take the place of platinum were it obtainable in large enough quantity. *Ruthenium*, "Russian metal", is also very rare, and has not been used practically; but *palladium*, named after the planet Pallas, has many valuable properties. Beautifully white, it does not tarnish as silver is so apt to do, and is very suitable for making the engraved scales of degrees used by astronomers. Dentists sometimes use it instead of gold for filling teeth, and the wonderful power it has of absorbing hydrogen, as blotting-paper sucks up water, makes it most useful in gas analysis. A thin sheet of the metal is able to take up nearly four hundred times its own bulk of hydrogen, and when it is heated the gas is all driven out again. Use was made of this extraordinary property in the experiments by which the American chemist, Morley, found the exact chemical composition of water to a greater degree of accuracy than had been attained by any of the many other experimenters who had tried to solve the problem. Water is the most important of all compounds, and an exact knowledge of the proportions of oxygen and hydrogen it contains is one of the main foundation-stones of the building of chemical science. It is interesting to note that the trowel with which this foundation-stone was "well and truly laid" was

constructed of an out-of-the-way metal whose very name is, perhaps, unknown to the majority of the people who, often without knowing it, owe to the science of chemistry many of the comforts and conveniences of their lives.

Amongst the siphons of soda-water, lemonade, and ginger-ale which you may see in shops there will be some labelled "Lithia Water". These contain a small quantity of a metal about as unlike as possible to the metals just described. Although white and silvery in appearance, *lithium* is the lightest of all metals, just as osmium is the heaviest. If these metals were made into wires of the same thickness it would take a piece of the lithium wire more than 1 yard long to weigh as much as a 1-inch length of the osmium wire. Lithium swims on water and even on petroleum, whereas platinum, iridium, and osmium sink in quicksilver, on which an iron ball floats like a cork on water. Lithium means the "stone metal", and it was given this name because it was at first thought to exist only in the mineral kingdom. This has been proved to be incorrect, for small quantities of it are contained in certain vegetables, and it can be detected, for instance, in cigar ash. If a platinum wire is touched against a particle of a lithium compound moistened with hydrochloric acid and then held in a colourless gas flame, such as that of a Bunsen burner, a magnificent red light is seen. This property would make lithium most valuable in preparing fireworks were it not for the scarcity and high cost of the material. As it is, its chief use is in medicine. Lithium is by no means the only element which gives a peculiar colour to a

flame, and the "flame test" is much used in analytical chemistry. Common salt, which is the chloride of sodium, gives a brilliant yellow, so powerful that if sodium is contained in the substance being tested it is not generally possible to distinguish the colours that are given by the other elements present. Fortunately, however, we have the spectroscope, by means of which (as I hope you know) a mixed light can be split up into the various colours of which it may be composed, and these it places side by side somewhat as we see them in the rainbow. This wonderful instrument has led to many discoveries, new elements having been found by its means in the earth and in the air. More marvellous still, it enables the astronomer to find out much about the composition of the sun, the comets, and the stars.

The first triumph of the spectroscope as applied to the chemistry of the earth was in 1860, when Bunsen, after whom the gas-burner just mentioned is named, announced that he had found a new element in a certain mineral water in Germany. This element he named *caesium* (sky-blue metal), and the very next year he added *rubidium* (dark-red metal) to the list. Both these are metals, but metals of a very different kind from those we are accustomed to use. They melt about as easily as butter, and when thrown on water a flame bursts out. The colours after which they are named are not those of the metals themselves, but those which their compounds give to flames. Both are found in very small quantities, and, interesting as they are in their history and properties, neither is applied

to any useful purposes. Another element whose compounds give a fine red colour to flames is *strontium*. It takes its name from the village in Scotland near which a mineral containing it was first found. The metal itself is difficult to prepare and is not suitable for any practical use, but several of its compounds are valuable. The nitrate and chlorate are used for fireworks, and the oxide, known as strontia and closely resembling lime, is used to a large extent in purifying sugar.

There are many cases in which the compounds of a metal are of the greatest possible service, whilst the metal in a pure state is never seen except as a rarity in a museum. For example, it is only during the last few years that it has been possible to buy the metal calcium, and even now it is rather expensive, costing several shillings a pound and having only a very limited use. Yet the compounds of calcium occur everywhere and are applied to all sorts of purposes. Many building-stones are compounds of this element, and all mortars and cements are made from lime, which is its oxide. The marble used for mantelpieces in private houses, for columns and floors in churches, and for statues in art galleries is carbonate of calcium, and the glass of our windows contains the element. In other cases the pure metal is of more importance to mankind than are its compounds, and in yet others both are of about equal usefulness. *Barium* is a metal of the first class. Rarely seen pure, its compounds are widely used. The nitrate and chlorate are employed in making green fireworks, the sulphate is a substitute for white-lead in paint and in the manufacture of certain kinds

of paper and cardboard. Another element which gives a beautiful green colour to flames is *thallium*, the "green-twig metal". It was discovered by the spectroscope in 1861, and it is interesting to remember that the discoverer was the veteran chemist, Sir William Crookes, O.M., who has followed up this early feat with many brilliant discoveries. It is one of the rarer elements, and up till now no special use has been found for it. *Glucinum*, the "sweet metal", so called from the taste of some of its compounds, is interesting as being found in certain precious stones—the emerald and the beryl. It is white and hard, and the powder burns in air very brilliantly, but it is too costly to be used, like its plebeian relative magnesium, for flash-lights. Besides the gems just mentioned there are certain rare minerals in which glucinum is often present, but these are chiefly remarkable for containing compounds of a number of elements known collectively as the "metals of the rare earths".

The study of these began as far back as 1794, when Professor Gadolin discovered one in a mineral that had been found at Ytterby. Other similar minerals were afterwards found in small quantities in various places in Sweden, Norway, and Finland, and they proved to be extraordinarily complex. When the "rare earths" are spoken of the word "earth" really means the oxide of some metal, so that there are as many rare-earth metals as there are separate rare earths. How many these may be is not yet known for certain, but there are about fifteen of them upon which chemists are agreed and several others concerning which there is still dispute. Most elements

can fairly easily be separated from each other, but these rare-earth metals are so very much alike in their properties that it is exceedingly difficult to get them apart from each other, or to be sure that what is at one time thought to be an element may not be proved soon after to be a mixture of two or three different ones. An immense amount of work was done in this department of chemistry purely with the aim of increasing knowledge and making it exact; but the discovery of the incandescent gas-mantle gave a new motive to investigation.

It was found by Auer von Welsbach that a mixture of two of these rare earths, ceria and thoria, could be so applied as enormously to increase the light obtainable from coal-gas. Everyone knows the gas mantle. Woven of cotton, it is saturated with a solution containing the nitrates of the two rare metals, and when the cotton has been burnt away by the first firing the oxides of the metals are left as a kind of skeleton. This, heated by the non-luminous or "bunsen" flame within, glows with an intense light. In order to get the best results the two oxides must be present in certain proportions, about 1 part of ceria to 99 parts of thoria. The discovery of the mantle greatly increased the value of the rare-earth minerals. No longer did these simply supply material for Professor A to work at when he wanted to prove that the erbium or terbium, the dysprosium or didymium which Professor B had described as an element was not an element after all, but a mixture of two or three of those discovered several years before by Doctor Herr von C. On the contrary, large quantities were wanted for commercial purposes. Mining

engineers and geological experts were on the outlook for fresh supplies of the raw materials, and, as is often the case when the demand for an article greatly increases, the supply also increased.

The rare earths proved to be less rare than had been supposed, and minerals containing them were found in new localities, the most important being monazite sand from Brazil and Carolina. From this, by processes kept as secret as possible, the thorium nitrate is prepared which is required for the great mantle industry. The introduction of the incandescent mantle has enabled coal-gas to hold its own against electric lighting to an extent which would otherwise have been impossible. Named after Thor, the old Scandinavian war-god, thoria has indeed proved a mighty warrior in the great fight between coal-gas and electricity. There is another wonderful thing about the element thorium. It possesses, although to a far smaller extent, the marvellous property known as radioactivity and belonging to radium to so great a degree that in comparison with it even diamonds and rubies are cheap and common. Ceria, the other earth used in the mantle industry, is the oxide of the metal *cerium*. This is an interesting element. About as heavy as iron and about as soft as lead, it takes fire so easily that bright sparks fly off when it is struck with a flint or even scratched with a knife. When alloyed with iron it could be used as a substitute for matches, but as these can be made so cheaply, there is not much chance of any substitute becoming a serious rival or being used except as a kind of toy.

In the struggle between gas and electricity as

applied to lighting our houses and streets the rare elements are not all ranged on one side. Electric glow-lamps containing threads or filaments of various metals have practically taken the place of those containing threads of carbon. One of the metals used for this purpose is called *tantalum*. Only a few minerals contain this element, and, although it has been known for more than 100 years, a standard encyclopædia published in 1904 speaks of it as of no practical importance. This shows very clearly how dangerous it is to say that any substance is useless or that any advance in knowledge can have no bearing on the welfare of mankind.

To-day tantalum is in great demand for lamps, and many other uses are likely to be found for it. It is as hard as the best steel, and, when hot, can be made into wire that is exceedingly tough and strong. The enormous temperature of 5160° F. is required to melt it, a temperature as far above that of the molten iron that pours out of a blast-furnace as the temperature of that iron is above that of an iceberg in the Arctic Ocean or of the frozen desolations around the South Pole. Quite possibly there is a future before tantalum as a substitute for platinum as regards some of the many purposes for which that metal is employed. The wires used in the lamps are very fine, only about $\frac{1}{500}$ inch in diameter, so that the weight required is very small in spite of the fact that tantalum is very heavy. Another metal used for lamp filaments is *tungsten*. The principal mineral containing it is called wolfram, and this is found in various places in Europe, America, and Australia, as well as in our own country, in Corn-

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MAKING FILAMENTS FOR ELECTRIC LAMPS

The girls are engaged in the delicate task of making and mounting drawn tungsten wire filaments for Ediswan lamps. First the wire is tested, to make sure that the quality, strength, diameter and electrical resistance leave nothing to be desired; then skilful fingers mount the filaments on the glass stems, and the stems are sealed into the bulbs by special machinery.

wall and Cumberland. The metal is very hard, heavy, and about as difficult to melt as tantalum. Electric lamps of great efficiency are made with threads of the metal, but still larger quantities are used for quite another purpose. When ordinary steel is made hot and then cools it gets softer, and thus some kinds of tools which get heated by use would spoil or require to be rehardened from time to time. By the addition of 9 or 10 per cent of tungsten to the steel a "self-hardening tool steel" is made which is not affected in this way. Besides these uses of the element itself one of its compounds, known in trade as "tungstate of soda", is employed in dyeing as a mordant. This name "mordant", meaning "biting", is given to a chemical which makes the dye "bite" into the fabric so that it will not wash out. Another most important use of the tungstate is in treating flannelette so that it will not easily burn. Ordinary flannelette is very inflammable, and many deaths have taken place through garments taking fire. They might have been prevented if the dangerous material had been rendered safe by the use of this compound of tungsten.

There are several other metals used in small proportions for improving the quality of steel for certain special purposes, as I mentioned in Chapter III. One of these is *nickel*. If a chemical element could protest against being called by an inappropriate name, nickel would certainly have a right to complain. The word originally meant false or worthless, and was given to an ore found with the ores of copper and looking like them, but yielding no copper. About a hundred years ago it was found that this false ore con-

tained a new metal, and the name nickel has clung to it ever since. Really it is most valuable and useful, and during the last fifty years the annual output of it has increased from about 500 to more than 20,000 tons. It is not only mixed with steel to make it tougher, but is used for plating steel tools and instruments to keep them from rusting. The pure metal is most useful to the chemist for crucibles, basins for evaporating, and other vessels required in his operations. Alloyed with copper, zinc, and other metals it is called "German silver", and is used for many purposes. The better qualities of electroplated spoons and forks are made of an alloy called "nickel silver", covered, of course, by a layer of real silver deposited by electrical methods. In many countries, though not at present in England, alloys of nickel are used for making coins; and it is extraordinary that a coin of an ancient Eastern king, who had reigned about 235 B.C., was found on analysis to have the same composition as the modern "nickel" pieces current in France and the United States. To the electrician nickel is most useful, for alloys of it are used under such names as platinoid, constantan, rheostan, &c., for making wires of high electrical resistance.

Very like nickel in most of its properties, *cobalt* is but little used in the form of the metal itself. Some of its compounds, however, are very valuable, and, under the name of smalt, have long been used in making blue glass and certain paints. The chloride of cobalt, when dissolved in water, gives a pale-pink solution which may be used as an invisible ink. Words written with this liquid can scarcely be seen, but, on holding the paper before the fire, the writing

comes out in distinctly-legible blue letters. When taken away from the fire the writing soon fades, but can be turned blue again by warming as at first. The origin of the word cobalt is very curious. It comes from Kobold, the name given by the German miners of old times to a demon or spirit who was supposed to haunt the mines. *Chromium* owes its name to the colours of many of its compounds. The metal itself is contained in some forms of steel, known as chrome steel, and is used for making the projectiles of big guns and for other purposes which require great hardness.

Some of the compounds are of considerable practical importance. The green oxide is used in colouring glass, porcelain, and enamels, and in making green paint. Chrome yellow, chrome red, and orange chrome are chromates of lead. Bichromate of potash is made on a large scale direct from the chrome ironstone, the chief ore of the element. It is used for making most of the other compounds, also in photographic printing processes, in tanning, dyeing, calico-printing, in the bichromate battery familiar to every student of electricity, and for many other purposes. Another beautiful yellow used in painting is cadmium sulphide. This is composed of sulphur united with the metal *cadmium*. This element is found in small quantities in the ores of the much commoner zinc. It is whiter than zinc, and a little harder than tin. One of its compounds, iodide of cadmium, is sometimes used in photography, and the metal is employed in making a special kind of voltaic cell which the electrician uses as a standard for measuring the voltage of ordinary cells and batteries. Another use of

cadmium is in making alloys which melt very easily. These fusible metals are employed in making certain kinds of type, in copying woodcuts and so forth, because beautifully clear impressions can thus be obtained. When melted and poured into a mould most metals shrink as they cool and become solid, but these fusible alloys do just the opposite. They expand and force themselves into every little hollow and crevice of the mould and reproduce every detail exactly. One of these mixtures, called Wood's metal, melts when put into hot water. It is sometimes made into tea-spoons, which are used for playing a kind of practical joke. The spoon is quite hard and solid, but when it is put into a cup of hot tea the bowl melts off, much to the astonishment of the person who has had one given him and is stirring his tea with it.

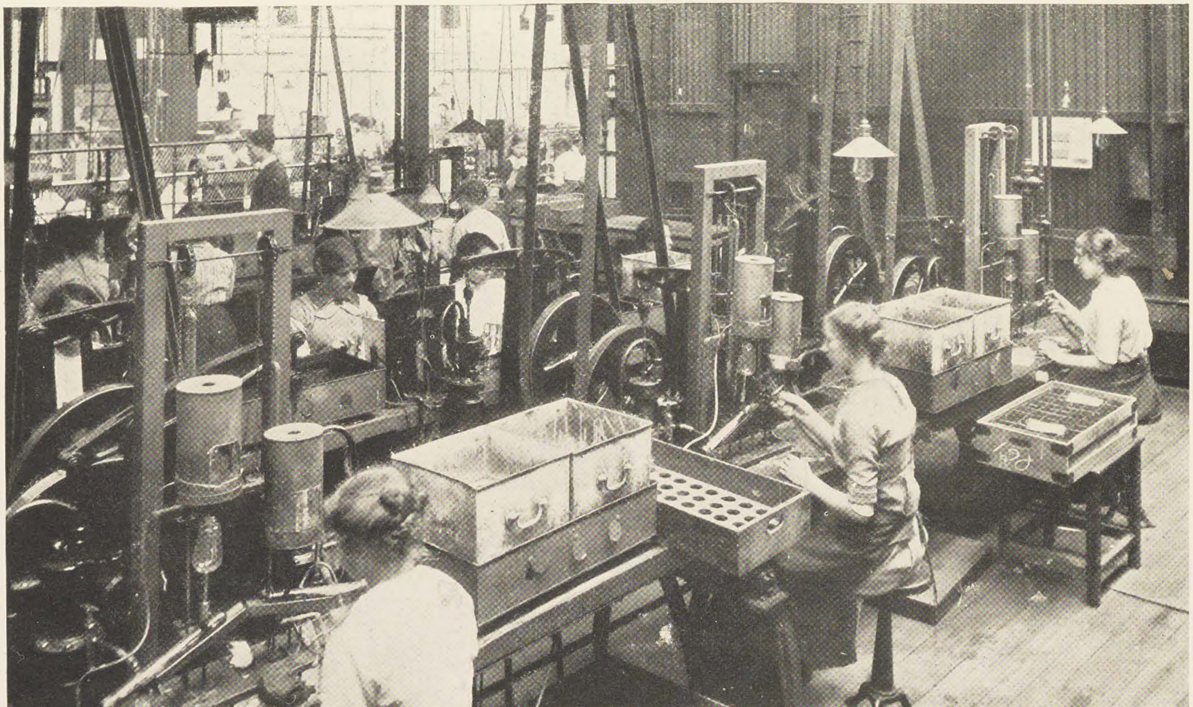
The fusible alloys do not always contain cadmium, but another metal called *bismuth* is always one of the ingredients. This is a very brittle metal, very bright, and with a rather faint but quite perceptible pinkish tinge. There are very few metals which have any positive colour; most are white or more or less grey. Copper is red, gold is yellow, and bismuth has this pink hue; but these are almost, if not quite, the only exceptions to the rule. Another special point about bismuth is that it is generally found native, that is, in the form of the metal itself, instead of being combined with other substances to form an earth-like ore. Several medicines are made from bismuth, and also a beautiful white pigment known as pearl-white. Another use of the fusible metals or alloys made by melting bismuth up with tin, lead, and sometimes cadmium, is in making safety-plugs

for steam-boilers. These plugs can be made to melt at almost any desired temperature by using proper proportions of the ingredients. Now, the steam in the boiler of an engine may be much hotter than steam from an ordinary kettle, and the hotter the steam the greater the pressure. Suppose a boiler is made strong enough to stand a pressure of a certain number of pounds to the square inch, and that something goes wrong—such as a valve getting jammed and refusing to act. The steam gets hotter, the pressure gets greater, and presently there is a burst. But if a safety-plug is used which will melt at a temperature a little higher than that at which the boiler is intended to work all will be well. In this case, if the temperature gets too high, the plug melts, the steam has a way of escape, and no explosion occurs. The automatic sprinklers sometimes fitted in factories and warehouses as a precaution against fires work on the same principle. When a fire breaks out a piece of fusible metal melts as soon as the place begins to get hot, and a shower of water begins to fall, perhaps before the watchman knows of the outbreak and long before the fire brigade could arrive with its engines.

Most people know the beautiful purple-coloured liquid used as a disinfectant and called Condy's fluid. The dark crystals of permanganate of potash, which give a similar liquid when dissolved in water, are almost as widely known. The element *manganese*, which these contain, is found in nature as a mineral pyrolusite. This is a compound of manganese and oxygen, and a very useful substance indeed. In glass-making it serves to remove from the glass the disagreeable yellowish colour which it

would otherwise have. Heated with hydrochloric acid it sets free chlorine gas, and this, absorbed in lime, gives bleaching-powder. The metal itself is hard, grey, and brittle. Although of little use when pure, the addition of a small quantity of it to steel improves its quality and makes it more suitable for many purposes. This manganese steel is used for boiler plates, train rails, and propeller shafts for steam-ships, whilst even such familiar articles as razors often contain a little manganese. Very various are the uses of this metal at the present day. It is extracted from a black mineral which in ancient times was quaintly considered to be a feminine kind of load-stone, differing from the ordinary or masculine load-stone by not possessing what we should now call magnetic properties. It was not very polite of our ancestors to take the absence of the power of attraction as a feminine attribute! There is, by the by, no real connection between magnetism, magnesia, and manganese, but in former times such a connection was supposed to exist, and hence arose the similarity of the names.

Several examples have already been given of metals used in making different kinds of steel. One other may be mentioned, and that is *vanadium*. This is quite a scarce element, but an alloy of it with iron, called ferro-vanadium, is now manufactured on a fairly large scale in France by means of the electric furnace, and this substance is used in making a special kind of steel. One part of vanadium in 500 of steel has as much toughening effect as 20 parts of nickel would have. The rapid progress of nearly all branches of science in recent times is partly due



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EXHAUSTING ELECTRIC LAMPS

The picture shows the girls seated at the pump benches in the Ediswan works, and the lamps attached to the exhausting pumps. The pumps produce the very highest vacuum obtainable, which is essential to ensure the long life of the lamps.

to the great extent to which workers in one branch are able to make use of the discoveries of those in other branches. It was said just above that the electric furnace is used in making ferro-vanadium, and this is only one of many examples of the advance made in chemistry through the growth of the science of electricity and the art of electric engineering. By means of the electric furnace the chemist is able to prepare alloys of metals having just the properties that fit them to meet the many fresh demands that arise. The motor-car, the aeroplane, the dynamo, all require special materials for their construction. The great treasure-house of the earth contains all sorts of precious things, but so many of them are locked up most securely. Science is the locksmith that forges the keys which will open the secret chambers and so render the jealously-guarded treasures available for the use of man.

The jacinth or hyacinth was much esteemed as a gem in ancient times, although it is now out of fashion. It is mentioned in the New Testament (*Revelation*, xxi, 20) as one of the "all manner of precious stones" which garnished the foundations of the wall of the New Jerusalem which the seer beheld descending out of heaven. This stone is a silicate of the metal *zirconium*, or at least such is the mineral to which the name jacinth is now given. Zirconium is one of the hardest of metals, so hard as to scratch rubies, which are generally ranked as, next to diamonds, the hardest of natural substances. Although no application has been yet found for the free metal, its oxide, zirconia, is used in making the rods for the Nernst electric lamp. Blended with 10 per cent of

magnesia, it has been made into crucibles in which platinum and quartz can be melted, a fact which bears testimony to the refractory nature of the substance.

Widely spread and closely meshed as is the net now cast to catch the rarer elements and compel them to do some useful service, there still remain many for which no actual use has been found. Amongst those which appear to stand idle while their relatives are hard at work are some that are deeply interesting on other grounds. I have always thought that the very rare metal *gallium* has a special interest on account of the history of its discovery. Just as the astronomers Adams and Leverrier foretold the existence of the planet Neptune before it had been sighted through the telescopes of the observatories, so did the Russian chemist Mendeléef prophesy, in the year 1869, that certain new metals would sooner or later be discovered, having properties which he described in considerable detail. This prophecy was no mere guesswork. Chemical theory, as Mendeléef understood it, had room for several new elements, and, confident in the truth of this theory, Mendeléef believed that such elements existed, and did not hesitate publicly to proclaim this belief. In 1875 a French chemist (Lecoq de Boisbaudran) found a new element which he named *gallium* (the French metal), agreeing in a most wonderful manner with the prophecy. A few years later the predictions of Mendeléef were fulfilled in two other cases by the discovery of two other metals, known, in honour of the nationalities of their discoverers, as *scandium* and *germanium*.

But in some respects the most remarkable of all the

rarer elements is *uranium*. The principal ore of this metal is called pitchblende, a dark-coloured mineral found in Cornwall, Austria, and a few other places. The metal is white and very heavy, and certain of its compounds have long been used to give a specially beautiful yellow colour to glass. So far there seems nothing very remarkable about uranium or the pitchblende from which it is made. But in March, 1896, it was proved by Professor Henri Becquerel that uranium and its compounds give off some kind of rays capable of acting on photographic plates. At first he thought that this was the same kind of thing already well-known in the case of various other substances. Most people have seen the luminous matchboxes that appear every year in fancy shops and places where Christmas presents are sold: these are prepared with a kind of paint which seems able to gather light during the day and give it out at night. But such an explanation was soon found to be unsatisfactory, for uranium that had been kept in a closed box in a dark cupboard for years gave out streams of rays just as freely as other specimens that had just been exposed to bright sunshine.

A week or so later another discovery followed. The new rays had electrical effects as well as photographic ones, and very soon apparatus was devised which enabled the intensity of this ray-giving power, already beginning to be called radio-activity, to be measured. The news of these discoveries stirred up others to take part in investigating the wonderful rays and the substances that gave them. Amongst these was a lady of Polish descent, Marie Sklowdowska, soon to be known and honoured everywhere under

her married name as Madame Curie. She set herself to determine to what extent the extraordinary properties of uranium were shared by other substances, and was gradually led on to discover the wonderful element she called *radium*. Only very small quantities of this are obtainable, even from the sources that contain most of it. The first batch was made from about a ton of material, and from this resulted between three and four grains, or less than the hundredth part of an ounce. The total amount that has been extracted up to the present is very small, and the prices charged for it would have seemed a few years ago as incredible as the properties of the substance. What are these wonderful properties which make radium appear to belong to some dreamland of magic and miracle rather than to the world of everyday waking life? Only a very imperfect sketch of an answer can here be given to this question, seeing that the whole of this volume might easily be devoted to this one thing alone, but the following will give some idea of what radium is and does.

In the first place, then, radium and its compounds are luminous in the dark. A little glass tube containing a tiny portion of it is like a tiny glowworm. Then it continually generates heat, so that it is always a little warmer than surrounding objects. Radium owes its name to the rays which it continually emits, rays which are of three kinds, each capable of producing special effects, and called, after the first three letters of the Greek alphabet, alpha, beta, and gamma rays. Alpha rays are tiny particles of matter charged with positive electricity and shot out at a speed of more than 10,000 miles a second. When these alpha

particles have lost their electric charges, they prove to be atoms of a new element called *helium*. This is a gas, and is named after the sun, because it was first discovered by means of the spectroscope in that body. The beta rays are particles smaller still, and fly off with still greater speed. They either have, or perhaps are, charges of negative electricity, and are known as electrons. The gamma rays are similar to the X-rays, which enable surgeons to locate a bullet in a wounded soldier, and are used in the treatment of some skin diseases.

Besides the rays, radium also yields a curious kind of heavy gas, luminous in the dark, and also able to give out rays. This is called *niton*. In furnishing these new elements radium slowly wastes away, but so slowly that thousands of years would elapse before a specimen of it would have entirely disappeared, and a very long time would have to elapse before any perceptible loss of weight would occur. The niton which is formed from radium is as extraordinary as radium itself. By great cold it has been condensed to a liquid and frozen into a steel-blue solid, which glows in the dark like a tiny arc-lamp and becomes orange when cooled still more strongly. This gas has but a short life. As it shoots out rays it gradually disappears, and a new stage is reached in the wonderful drama. Just as radium gives rise to niton, so does niton in its turn produce a new substance, known as *radium A*. This also is but a temporary halting-place. To radium A succeeds *radium B*, which gives rise to *radium C*, and so on.

It is nearly, but not yet quite certain that the last stage in the marvellous series of changes is the pro-

duction of the element lead. If this be true, radium may be described as the ancestor of lead, and it is the descendant of uranium, from which it is with extreme slowness being formed. A few years ago the idea of one chemical element changing into another would have been considered wild and fantastic. Now opinions have altered, and it is known that two at least of the elements, uranium and thorium, are slowly but surely disappearing. As they die, other elements are born, which in their turn pass away into others, until at last some stage is reached in which the process stops. Some at least of the ordinary elements may be descended from ancestors which have long since disappeared. At present we can only look on and watch these changes which radium and the other elements of like properties undergo; we can neither hasten them nor delay them. But, remembering that twenty years ago nothing whatsoever was known about these subjects, and thinking of the extraordinary store of knowledge that has been got together in that short time, must we not conclude that marvellous and miraculous is the human mind which can collect and arrange them? The age of wonderful discoveries is not over; rather it is just beginning. Farther and farther does science penetrate into the mysteries of Nature, and more and more wonderful are the trophies which are borne triumphantly away from the great treasure-house of the earth.

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